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THE SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

JULY, 1923

THE DEBT OF SCIENCE TO PASTEUR

By Professor GARY N. CALKINS
COLUMBIA UNIVERSITY

It is hardly possible to put in a few words an adequate expression of the debt of science to Pasteur! A consummate master of the method of science; not a medical man, yet by his achievements establishing medicine in all its branches on a scientific foundation; not a biologist, yet by sheer force of scientific method able to shape and to securely place the keystone in the arch of our conceptions of living nature. And what a model for all men was his tolerance of the shabby quarters in the garret of the Écolé Normale in the Rue d'Ulm! Here, surely, he demonstrated the fact that achievement is not the reflected radiance of a palace of research, but comes from within.

"Wherever he went," says Duclaux, "Pasteur was an initiator. Guided by an imagination so adventurous and at the same time so well controlled, we are constantly on the borders of new countries, but we journey in security." All of these countries are in the territory of biology and it is difficult to draw the line between those which are strictly biological in a modern sense, those which are chemical, and those which are strictly medical. His mind worked progressively, always building a new edifice on the foundation of a principle which he had previously demonstrated. We irresistibly look back of his final achievements in preventive medicine, to his earlier work on chicken cholera and splenic fever and from this, still back to that inspiration, the germ theory of disease, which grew up with his investigations on the cause and prevention of silkworm epidemics. Here, again, a great truth was but crystallization in a mind saturated with conceptions of the varied activities of minute organisms responsible, as he had shown, for the multiple phenomena of fermentation. And who shall say that the explanation of these phenomena was not the outcome of his first

work in chemistry on the rotary power of crystals and molecular asymmetry?

Most of Pasteur's great discoveries were the results of investigations undertaken in response to economic or human needs. So it was with fermentation. In 1856 a Lille manufacturer, having difficulty in the making of beet root alcohol, came to Pasteur for advice, and the latter consented to make some experiments. As a result of these experiments a new road was opened, one road which was to lead him to some of the most important discoveries in the history of science.

Ideas on fermentation at this time were confused and highly speculative, even those of a master as great as Liebig were little in advance of the shrewd guesses of the 17th century. The atomic theories of Descartes had already found their way into chemistry when Willis, and later, Stahl in the latter part of the 17th century, adopted them in the explanation of alcoholic fermentation. "Every substance," said Stahl, "in a state of putrefaction easily transmits this state to another body still free from decay. Thus it is that a similar body, animated already by an internal movement, may, with the greatest facility, involve in the same internal movement another body still in repose but disposed by nature to a similar movement."

This mystical conception, supported by many of the great chemists of the last century—Lavoisier, Gay Lussac, Berzelius, Liebig—became firmly established. Lavoisier, infatuated with oxidation, paved the way for Gay Lussac to see in it the chief agent in fermentation, although, indeed, the latter, and Lavoisier before him, had found it necessary to add a little of that corpuscular substance which Leeuwenhoek had discovered in 1680 and which had become known as yeast.

Leeuwenhoek, himself, suspected that the corpuscles in yeast were living organisms, a suspicion confirmed and proved by observations and experiments by Helmholtz, Schwann, Kützing and Cagniard-Latour in the first half of the 19th century.

The part played by the living yeast corpuscles formed the crucial problem when Pasteur entered the lists. To him Liebig's conception of fermentation was particularly repugnant. This great chemist while admitting the organic nature of yeast, held that fermentation is due to extremely alterable substances which easily decompose. The molecular activity brought about by this decomposition sets in motion the molecules of the fermentable matter. Yeast, when dead, forms such an alterable substance and imparts its disintegrating activity to the fermentable sugar.

Liebig's purely dynamic conception was everywhere accepted and taught, and was applied not only to alcoholic fermentation,

but to all decomposition and putrefaction. Why, it was asked, should alcoholic fermentation be dependent upon yeast if other types of fermentation occur when no yeast is present?

Pasteur's solution of the problem is typical. He struck first at the widely accepted view that fermentations are due to unknown molecular forces. He demonstrated experimentally—first with lactic fermentation, that different kinds of activities of similar nature are brought about through the vital activities of living organisms, and he showed that each type is dependent upon its own specific kind of microorganism. In the case of alcoholic fermentation it has become part of the routine in every biological laboratory to perform his crucial experiment of growing pure yeast in water containing sugar, ammonium tartrate and mineral salts of calcium-phosphorus, magnesium, etc., but with no trace of organic nitrogen. Here the yeast does not die and disintegrate as Liebig's theory requires. On the contrary it lives and multiplies vigorously at the expense of the sugar. Alcohol, carbon dioxide, glycerine and succinic acid are left after the yeast takes what it needs as food from the sugar.

Pasteur was not content to rest with this demonstration. His clear-thinking mind reached beyond the horizon of fermentations to the intricate play of living things whereby the equilibrium of nature is maintained. He saw the part played by microorganisms in putrefaction and decomposition; he saw how, through their activities, the protein matter and all substances composing the bodies of animals and plants are ultimately reduced to ammonia, carbon dioxide, mineral salts and water and restored to the earth. Here, taken up by green plants, they are brought back again through photosynthesis to the realm of living protoplasm. He thus added the physical basis of life to Helmholtz's principle of the conservation of energy and gave to general biology, for the first time, a realizing sense of the marvelous cycle of matter and energy in living nature.

His studies on fermentation opened up a new series of problems. On every side arose the inevitable question: Whence come these minute living organisms? Do they develop spontaneously or do they come from pre-existing organisms like themselves?

In all ages, spontaneous generation has been the refuge of the uninformed and the hopelessly ignorant. Even as late as the 17th century, eels, salamanders, lizards, flies, bees, etc., were regarded as originating by spontaneous generation, and we find a noted chemist of that day gravely handing down to us an infallible recipe for making mice: "Place a piece of soiled linen in a vessel; add a few grains of corn; and in twenty-one days the mice will be there, fully adult, and of both sexes."

Such views strike us as too silly for belief. But in those days tradition and superstition were powerful factors which few dared to question. Redi, and later Vallisneri, both Italian physicians, were among the first to doubt and to follow up their doubts with experiments. The former proved that flies would not develop from rotting meat if the latter is properly covered by gauze. He noted that flies, attracted no doubt by the odor of the meat, deposit eggs on the gauze. He saw that larvae develop from the eggs, and flies from the larvae. Vallisneri proved that the worm-like grub found in fruit does not develop from the fruit, but from an egg deposited there by an insect. Little by little the old traditions were replaced by facts, and so far as these larger animals are concerned, the theory of spontaneous generation was abandoned.

In 1675, however, the world of microscopic life was opened up by the Dutch naturalist Leeuwenhoek. Minute living things were found to develop in pure rain water, as well as in all moisture where organic matter was present. How could their origin be explained save through spontaneous generation? The old tradition, reinforced, came back, and experiments analogous to those of Redi and Vallisneri in the hands of Buffon, Needham, Pouchet, Joly, Bastian and others appeared to verify it. Other experiments, with conclusions opposed to spontaneous generation, by Spallanzani, Schultze, Schwann and others were incomplete and failed to carry conviction. The idea that specific living germs are present in the air was inconceivable, and partisans of spontaneous generation certainly had the best of it in argument. "We are mindful," they would say, "of a certain experiment of Gay Lussac where a small amount of the must of grapes when brought in contact with a few bubbles of air would begin to ferment. You say these bubbles brought with them some germs of yeast, but they must bring something else. How could a bubble of air bring germs of yeast into one fluid, something else into an infusion of hay, and still other things into meat infusion? That makes a great many germs," and, Pouchet added, "the air thus peopled would have the density of iron."

Prepared by his previous experience with fermentations, Pasteur was ready. With infinite patience experiments were planned and carried out. Nutrient, but sterile media in sealed flasks, exposed to heated or filtered air, in the great majority of cases remained sterile; so, too, when exposed to rarefied mountain air.

From his discussions with Pouchet and Joly there followed the conclusive proof that germs are present in the air we breathe; from his discussions with Bastian, who remained a heterogenist until his death a few years ago, came the proof that solids and liquids, as well as the air, are carriers of germs. It was from these discus-

sions, particularly from those with Bastian, that the modern technique in bacteriology and in surgery has been developed, although not by Pasteur alone.

The ghost of spontaneous generation, however, was not yet laid. Notwithstanding the fact that the media used by Pasteur were apparently sterile and the air supplied was germ-free, an active development of micro-organisms occurred now and then. Such exceptions were eagerly seized by his opponents as evidence that in these flasks only were the proper conditions for spontaneous generation provided. Pasteur's experience had not brought to light the fact that the spores of some organisms, *e.g.*, *Bacillus subtilis*, have the power to resist prolonged heating at high temperatures which kill actively living germs. This fact was later demonstrated for the first time by Jeffries Wyman. Such heat-resistant germs were the cause of fermentation in Gay Lussac's must of grapes; they developed in Pouchet's sterilized hay infusion, and they were present in Bastian's samples. Gay Lussac affirmed the phenomenon to be due to oxygen; Pouchet and Bastian to spontaneous generation; Pasteur to germs of the air. All were mistaken. Later it was shown that the heat-resisting spores develop only in the presence of atmospheric air. Pasteur was right so far as the presence of a germ is concerned; Gay Lussac was right so far as the need of oxygen was concerned; Pouchet and Bastian were hopelessly wrong, and the theory of spontaneous generation has not since been revived.

Pasteur was by no means satisfied with his incomplete demonstration that, like higher types of organisms, all types of germs are derived from germs similar to themselves. He was planning further extensive experiments in this direction when he was called upon to undertake a new and an entirely different kind of work. The great silk industry of southern France, already vastly reduced, was threatened with complete ruin by a deadly epidemic amongst the silkworms. In Italy, Spain, Austria, Greece, Turkey and even in China, the conditions were the same. In Japan only were there healthy moths. Pasteur was asked to investigate the disease and, if possible, to find a remedy.

This is the point in Pasteur's career where, if at all, we can draw the line between his foundations and his later triumphs, between his achievements in general biology, and those in preventive medicine. During the six years which he devoted to the silkworm problem, there gradually developed in his mind the conviction that many human diseases, like the silkworm disease, are due to micro-organisms. Duclaux writes of this period: " . . . Nothing can be more curious than to see Pasteur at close quarters with a bristling, complicated problem, beginning by being deceived about it,

by seeing things the wrong side to, but led back continuously to the truth by experiment, and ending by unravelling all the complications. I do not know a more beautiful example of scientific investigation. It is the first camp on a route wherein he found immortality; the earlier discoveries had given him only glory."

The silkworm disease was not new and considerable information had accumulated in regard to it. The body wall of infected worms is covered with small black spots, giving it a peppered appearance. This had led de Quatrefages to name the disease pebrine. Tissues and organs of such insects had also been found to be riddled by curious, minute corpuscles which were first seen in 1849. Some investigators looked upon these corpuscles as definite living causes of the disease, which Naegeli 1857 named *Nosema bombyces;* others interpreted them as normal products of all moths. Six years before Pasteur began his work Osimo and Vittadini, Italian sericulturists, had recommended that all eggs showing corpuscles on microscopical examination should be discarded. Their advice was regarded as fantastic and unnecessary, particularly after Cantoni and Balotti in 1863 had obtained infected moths from eggs without corpuscles and had concluded that microscopical examination was as worthless as all other remedies.

All of this was unknown to Pasteur when he went to Alais in 1865. From the available literature, he believed at once that the key to the problem lay in the famous corpuscles. He looked for them and found them in abundance. Beginning his experiments a little at random he soon made an important observation. Of two broods of silkworms which he was studying, one was a fine, healthy lot which had finished its larval life and had ascended the heather to spin cocoons. The other brood had dragged along and looked badly; the worms were drooping, ate little, and the harvest of cocoons was a failure. On microscopic examination he found that the fine, healthy worms were riddled with the corpuscles, while the more degenerate lot showed few or none. Investigation showed him that the phenomenon was widely spread in the region about Alais.

Here at the outset was a blow to the view that the corpuscles had a causal relation to the disease. Its effect was so lasting that for two years Pasteur was thrown off the track. He drew the conclusion that of the two broods, both had the same disease, but the stronger lot had contracted it later in life and had sufficient vigor to form cocoons and moths, while the weaker lot had acquired the disease earlier and had succumbed before the chrysalis stage. This result led him to believe that the corpuscles were not the cause of the disease but were characteristic degeneration products of the tissues, and formed as a result of the disease. It is interesting that the practical application of this false idea was as successful as

though a true interpretation had been found. He advocated and practiced the selection of non-corpuscular eggs from moths likewise free from them. Their absence from such material would indicate that the disease was at least not advanced and would ensure a successful crop of cocoons. He thus returned to the method advised by Osimo.

With eggs thus free from corpuscles, and with eggs and larvae containing the corpuscles, he had material necessary for the experimental method of research. Batches of eggs from infected and non-infected lots were grown under identical conditions; corpuscles were always abundant in larvae and moths from eggs which contained corpuscles, and in many cases from eggs free from corpuscles, but always a good proportion of healthy insects came from the latter group. He also found that by feeding healthy larvae with food containing corpuscles, the tissues and organs of the moths which developed were loaded with them. This would seem to be pretty conclusive evidence that pebrine is due to the corpuscles, but with singular obstinacy he still clung to the view that corpuscles are effects, not causes of the disease. As one of his biographers has said: "He had, until the end of two years, marched directly towards the promised land, but he had marched backwards. As soon as he turned about the whole of his conquest appeared to him at once." He made this turn in 1867. Improvements in technique gave him healthy broods entirely free from corpuscles. He inoculated some of these through the body wall as well as through the mouth with contaminated food. He allowed infected larvae to inoculate healthy ones through lacerations made by claws, and in all cases pebrine followed. The evidence became irresistible and long after his assistants and collaborators were convinced, he himself was forced to see in the corpuscle the cause of pebrine. But how account for the fact that many worms died without showing any trace of the corpuscles, as was the case in his earlier observations? How account for the fact that some of his own healthy eggs in the hands of less experienced culturists gave rise to diseased worms? As a result of his experiments with this aspect of the problem he threw himself down one day in a laboratory chair, utterly discouraged, saying: "Nothing is accomplished; there are two diseases."

Nevertheless he saw the way out, and found ultimately that this second disease, known as flacherie, is entirely intestinal like human typhoid or cholera, and is due to a widely distributed bacillus. Worms with reduced vitality; worms in unhealthful surroundings succumb to it, while healthy and well cultured worms, although they may harbor the bacillus, do not become diseased. To prevent it he proved that it is only necessary to rear the larvae in clean, well ventilated hatcheries. From these six years of study Pasteur got

a deep and lasting impression first, of the idea of receptivity or susceptibility of individuals to germs; second, of the effect of unsanitary conditions in enhancing this susceptibility; third, of the idea of pre-disposing hereditary conditions and defects; and fourth, of the idea of differences in virulence of different strains of the same organism of disease. This last idea he developed later in studies on attenuation and vaccines.

Some further groundwork was necessary, however, before he was to throw the light of his imagination over the dark field of human disease. The occasion for this was furnished by the Franco-Prussian war when, in 1871, without opportunity or finances to carry out his dreams of research, he was persuaded to study the manufacture of beer in order to save France the expense of importing it from across the Rhine. The result of the experiments which followed, and of the book he wrote on the subject, enabled the French brewers to compete successfully with the best products from Germany and Austria. He proved that the diseases of beer are always due to the development of microorganisms which are foreign to good fermentation. One, and a most important discovery, was that yeast and certain molds like Mucor will thrive under proper conditions with oxygen of the air, that is, under aerobic conditions. If air is withheld, however, they have the ability to thrive under anaerobic conditions, when, as reducing agents, they get the needed oxygen from the most favorable source, which in fermentation is sugar.

Through other experiments on the diseases of wines he proved that natural fermentation is due to wild yeasts on the surface of the grape, and that such fermentations can be prevented by growing grapes in a properly protected yeast-free soil.

This latter fact led to his first clear statement of possible public prophylaxis against human disease germs: "Must we not believe by analogy," he wrote in 1879, "that a day will come when preventive measures of easy application will arrest human plagues which at one blow desolate and terrify whole populations, as did yellow fever in its recent invasion of the Senegal and the valley of the Mississippi, or the bubonic plague which has raged on the Volga."

Here, finally, the stage was fully set for his last great scene in the drama of microscopic life. Demonstration of the rôle of germs and of their control in the economic life of France, whereby millions of francs were saved annually in the silk, wine and beer industries alone, was introductory to the demonstration and control of their multiple activities in human disease.

Pasteur never qualified as a taxonomist. He apparently never experienced the pleasure of a naturalist in finding and describing

new species. He knew very little about the zoology of the silkworm organism; he cared nothing about morphology as such. It is related that a zealous microscopist once brought to his notice in carefully guarded words the fact that what he had called a coccus was in reality a very small bacillus. "Ah," said he, "if you only knew what little difference that makes to me." His great interest lay in the relations of the microorganism to its host; the relation between the physiological activity of the germ and the physiological activities of the invaded organism. He was not the kind to wade in the shallow waters of classification; if a deep subject appealed to him he dove to the bottom of it.

We have seen that, with fermentation, spontaneous generation and the silkworm diseases, he was not the first to enter the field. So it was with human disease. When he began his experimental studies on splenic fever, several pathogenic microbes had already been discovered, and Koch had just published his famous work on the spore of anthrax. He was, however, without precursor in the field which he made his own. No one before him had found out that the vitality of a germ determines the severity of the disease; no one before him was familiar with the conflict which occurs between the human organism on the one hand and the disease-causing organism on the other; he was the first to know of the products of bacterial action which we now call toxines; and no one before had recognized the importance of building up the resistance of the host by use of attenuated germs of the disease. He had to oppose almost single-handed the traditional and accepted view of the medical profession that viruses and living organisms are different things. The old conception of viruses, quite as mystical as Liebig's conception of fermentation, was maintained by many noted pathologists until within a comparatively recent period. The empirical results of vaccination against smallpox were, indeed, known, but the explanation was as remote then as is our knowledge to-day of the life history of the organism which causes it.

When Davaine with Rayer discovered the bacillus of anthrax in 1850 and interpreted it as the cause of the disease, the medical profession scornfully cried: "How can the great strength and vitality of a horse or an ox be threatened and destroyed by this miserable little rod which can be seen only with a microscope?"

The final proof came through application of the method, devised by Pasteur, of growing the organism in pure cultures. The history of splenic fever furnishes an interesting parallel with the silkworm diseases. Leplat and Jaillard had denied the conclusion of Davaine and Rayer that the microscopic rod was the cause of the disease, for, inoculating rabbits with putrid blood from an anthrax victim, the rabbits died and no anthrax bacilli could be found in

them. As the organism of flacherie as well as the organism of pebrine might cause the death of silkworms, so might some other organism kill rabbits as well as the anthrax germ. The proof of this was demonstrated by Pasteur and the group of organisms causing gangrenous septicemia or blood poisoning was discovered. With this proof came also the demonstration of the principle that a common microbe under aerobic conditions may be harmless, while under anaerobic conditions it is pathogenic.

I do not intend to enumerate all of the discoveries made by Pasteur as a consequence of his entry into the field of human diseases. Each successive discovery carried him a little nearer the goal of vaccines and preventive medicine. Working with the vibrio which causes septicemia, he found that cultivation in certain media gave weakened strains, while other media gave fully virulent ones. The significance became apparent in his studies on chicken cholera. Experiments on this latter disease were begun in 1879. The organisms were easily obtained and cultivated on broth; inoculations proved fatal to chickens and rabbits and to guinea pigs if the latter were inoculated in the veins. If guinea pigs were inoculated in the skin only a local abscess was formed and the animal was only slightly affected. It would thus become a carrier or a source of infection for other animals. Some chickens also seemed to recover from the disease, but died after some weeks or months. What was the reason for this relative immunity? The answer came with a clearness which was as startling as it was sudden.

After a vacation of some weeks experiments with the chicken disease germs were renewed. Chickens were inoculated with the old cultures which had been left during the vacation. These chickens did not die nor did they seem to be much affected. After repeated attempts the laboratory staff were about to throw away the old cultures and begin with new ones, when it occurred to Pasteur to inoculate those same chickens with fresh, virulent cultures of the organism. To the surprise of all, including Pasteur himself, these chickens resisted the inoculations and remained normal. Fresh chickens brought from the market and inoculated died of the disease, thus showing the virulent potency of the culture. With these observations and experiments the secret of vaccines was out; attenuation or reduced vitality of the germ so changes it that, upon inoculation, it causes a reaction which enables the victim to successfully resist later inoculations of the same germs in their full virulence.

Studies on vaccines then supplanted all else. It was soon shown that attenuated germs could be maintained permanently in the attenuated condition; that spores from attenuated germs would develop into organisms with the same attenuation, and capsules of

different kinds of vaccines were prepared, ready for shipment to all parts of the world. Every one who has read the life of Pasteur knows about the spectacular demonstration at Melun where out of 50 sheep inoculated with virulent anthrax bacilli, 25 that had been previously vaccinated with attenuated virus, remained alive and normal, while 25 that had not been vaccinated, all died.

The study of animal diseases thus led to principles which, there was every reason to believe, would apply with like results to human diseases. Splenic fever, due to the anthrax germ, indeed sometimes occurs in man, but its occurrence is so rare that it arouses no apprehension.

It was quite otherwise with rabies or hydrophobia. Here was a disease the thought of which brought terror to every living soul, and it was to this disease that Pasteur brought to bear the full weight of his experience with microorganisms. Again using animals, dogs in particular, he was able to study every phase of the disease. The seat of infection was traced back from the saliva to the central nervous system; inoculation by trepanning was found to be the quickest and most effective means, and fragments of infected brain or spinal cord would invariably convey the disease. Repeated experiments proved that attenuation of the germ, which by the way has never been isolated, is brought about by exposure of the infected tissues to the air. Strips of such tissue were thus exposed daily for a period of 15 days and, in treating humans, the victim of a rabid animal was first inoculated with the material from a strip 15 days old; then after 24 hours, with a strip exposed for 14 days and so on until the victim was inoculated without harm with material taken fresh from a rabid animal. Such treatment of rabies was possible, and effective, because of the long incubation period of weeks or months in a human being after infection.

This was the crowning work of Pasteur's life; to us it was the last stride in a long series of logical steps; to the popular mind, especially in France, it was a miracle. Almost every one in France was happy to contribute at least a few sous for the erection in 1888 of a monument to Pasteur. In this monument, the Pasteur Institute, on the rue Dûtot in Paris, Pasteur, weakened by a stroke of paralysis in 1868, spent the last years of his life. In it to-day, characteristic activity in all matters pertaining to disease still keeps alive the traditions of the master.

On the occasion of his reception in the Académie Française, Pasteur was thus addressed by Ernest Renan: "That common basis of all beautiful and true work, that divine fire, that indefinable breath which inspires Science, Literature and Art—we have found it in you. Sir, it is genius."

The debt of biology, the debt of medicine, the debt of all science to Pasteur is a debt to that indefinable breath of which Renan

spoke, and no one branch of science can claim a monopoly of Pasteur's genius.

Reviewing from the vantage point of to-day the position which Pasteur occupies in the history of science, free now from the shocks to prejudice and superstition which followed in apparently endless succession from his work, it would seem that the greatest expression of his genius lay in the glorification of scientific method—observation, deduction, experimental proof. Through these things his life-work, in the words of Renan again, "is like unto a luminous track in the great night of the infinitesimally small; in that last abyss where life is found."

Vallery-Radot quotes Pasteur as saying on one occasion: "A man of science should think of what will be said of him in the following century, not of the insults or the praise of one day."

In commemorating Pasteur's birth, audiences throughout the civilized world have heard little or nothing of the insults, but in this "following century" have united in one great wave of praise. He did become a teacher as his father so ardently wished, not indeed in the humble college at Arbois, not only at the great universities of Strasbourg, Lille and the École Normale, but a teacher at whose feet the entire world still sits in grateful appreciation.

How can we compare the life of Pasteur and of that other great scientist the centenary of whose birth was also commemorated last year—Gregor Mendel! Mendel was born in July, 1822; Pasteur on December 27 of the same year. I know of no other two scientific men whose lives present so striking a contrast. The one, working for fifty years in the spotlight of public approval, planned and developed every stage in the construction of a marvelous scientific edifice on foundations which he himself had laid. The other, working for seven years in the cloistered seclusion of a monastery at Brünn, alone knew that his work was good. Its full value he never knew. The one, full of honors, received from all lands, ending his career peacefully amid the scenes of his triumphs; the other, spending the later years of his life in fruitless wrangling, died comparatively unknown. The one saw as a result of his work the foundations of stereo-chemistry, of the germ theory of disease, of bacteriology, of serology and of preventive medicine; the other had been gone many years before his great service to the science of genetics was known and recognized.

Both were alike in devotion to truth; both were alike in respect to patience and perseverance in experimentation, and in attention to detail. Both had imagination.

The recognition of Mendel's genius, though tardy, has been generous, sincere and universal. This following century has now crowned him, as the last century did Pasteur, with the wreath of immortality.

THE CENTENARY OF LOUIS PASTEUR[1]

Pasteur and the Science of Chemistry

By Professor JOEL H. HILDEBRAND
UNIVERSITY OF CALIFORNIA

You who have come this evening to honor the memory of Louis Pasteur have been familiar, even from childhood, with some of his contributions to science other than chemistry. You drink pasteurized milk. You have learned that certain diseases are caused by germs and that it is possible to prepare anti-toxins which will come to our rescue when our bodies are invaded by alien hosts of bacteria. On the other hand, the nature of his contributions to chemistry is not easily understood and their significance is not generally appreciated by the laity, so that it would be quite excusable for you to wonder what justification there may be for my presence upon this platform. You may not have known before this evening that Pasteur was educated as a chemist and devoted himself chiefly to research in pure chemistry during the first years of his research career, and further, that during this time he made discoveries of fundamental importance, probably not inferior in value to those later discoveries in other fields which are the objects of more popular appreciation.

Since this is the case, and since his own work can speak louder in his praise than anything else, it is my purpose to endeavor to explain something of the nature and significance of his chemical contributions during this period. As a chemist I hasten to add that I do not abandon all claim in behalf of chemistry for a share in the glory of his later work. Much of it is still chemistry though shared with what we are pleased to call other branches of science, and I may even venture to suggest that he was helped to some of his later discoveries by his unusually good training in the more fundamental science, and through his fortunate escape from the large measure of traditional dogma which he would have been taught, at least at that time, had he been trained chiefly in medi-

[1] Delivered at the Pasteur Centennial celebration at the University of California, February 1, 1923. The address on "Pasteur and the Science of Biology" by Professor Charles Atwood Kofoid was printed in THE SCIENTIFIC MONTHLY for June.

cine or surgery. A fresh point of view is of great value in scientific discovery.

But I will not risk retort from my colleagues to follow by further disputing the field with them, and I therefore return to my main purpose.

In 1808, 14 years before the birth of Pasteur, Malus had discovered that light can be polarized. A beam of light transversing a crystal of iceland spar is broken up into two beams in which the vibrations are at right angles to each other, instead of occurring in all directions as in the ordinary beam. By a suitable cutting of the crystal, making what is known as a nicol prism, one of these beams can be disposed of, leaving a single beam of polarized light. If a second nicol prism is placed behind the first, and in the same position, the light polarized by the first passes through the second unchanged; but if the second prism is rotated 90 degrees, so that the two prisms are "crossed," the light polarized by the first can not pass through the second.

In 1815, Biot, who later became a staunch friend and patron of Pasteur, discovered that, if between the crossed nicol prisms there is placed a plate of quartz, or any one of several liquids, including turpentine and solutions of sugar, camphor and tartaric acid, one of the prisms must be rotated in order again to extinguish the light, showing that these substances rotate the plane of polarization.

The mineralogist Haüy had discovered the existence of two kinds of quartz crystals, exactly alike except that one corresponds to the mirror image of the other, as do the right and the left hands, and which can not be made to coincide any more than a right hand can wear the left-handed glove. In these crystals the possible faces are not all present, some being present on the right-hand corners of certain other faces, while in other crystals they are present on the left-hand corners. Such crystalline forms are known as hemihedral or asymmetric.

In 1820, Sir John Herschel connected this hemihedrism with the rotation of the plane of polarized light, pointing out that one kind of quartz crystal rotates the plane of light to the right, while the other rotates it to the left.

The next step was a presentation to the Académie des Sciences by Biot of a remarkable note by Mitscherlich concerning certain salts of tartaric acid, the acid of grapes. It was as follows: "The double paratartrate and the double tartrate of soda and ammonia have the same chemical composition, the same crystalline form with the same angles, the same specific weight, the same double refraction, and consequently the same inclination in their optical axes. When dissolved in water their refraction is the same. But the dis-

solved *tartrate* deviates the plane of polarization, while the *para*-tartrate is indifferent, as has been found by M. Biot for the whole series of those two kinds of salts. Yet," adds Mitscherlich, "here the nature and number of the atoms, their arrangement and distances are the same in the two substances compared."

Pasteur in his own later account of his discovery says:

This note of Mitscherlich attracted my attention forcibly at the time of its publication. I was then a pupil in the École Normale, reflecting, in my leisure moments, on this elegant investigation of the molecular constitution of substances [would that there were more students who would use their leisure moments for such reflections and for reading such as Pasteur did! But to continue the quotation] and having reached, as I thought, at least a thorough comprehension of the principles generally accepted by the physicists and chemists. The above note disturbed all my ideas. What precision in every detail! Did two substances exist which had been more fully studied and more carefully compared as regards their properties? But how, in the existing condition of the science, could one conceive of two substances so closely alike without being identical? Mitscherlich himself tells us what was, to his mind, the consequence of this similarity: "*The nature, the number, the arrangement and the distance of the atoms are the same.*" If this is the case, what becomes of the definition of chemical species, so rigorous, so remarkable for the time at which it appeared, given by Chevreul in 1823—"in compound bodies a species is a collection of individuals identical in the nature, the proportion and the arrangement of their elements."

In short, Mitscherlich's note remained in my mind as a difficulty of the first order in our mode of regarding material substances.

You will now understand why, being preoccupied, for the reasons already given, with a possible relation between the hemihedry of the tartrates and their rotative property, Mitscherlich's note of 1844 should recur to my memory. I thought at once that Mitscherlich was mistaken on one point. He had not observed that his double tartrate was hemihedral while his paratartrate was not. If this is so, the results in his note are no longer extraordinary, and further, I should have, in this, the best test of my preconceived idea as to the interrelation of hemihedry and the rotatory phenomenon.

I hastened, therefore, to reinvestigate the crystalline form of Mitscherlich's two salts. I found, as a matter of fact, that the tartrate was hemihedral, like all the other tartrates which I had previously studied, but, strange to say, the paratartrate was hemihedral also. Only, the hemihedral faces which in the tartrate were all turned in the same way, were, in the paratartrate, inclined sometimes to the right and sometimes to the left. In spite of the unexpected character of this result, I continued to follow up my idea. I carefully separated the crystals which were hemihedral to the right from those hemihedral to the left, and examined their solutions separately in the polarizing apparatus. I then saw with no less surprise than pleasure that the crystals hemihedral to the right deviated the plane of polarization to the right, and that those hemihedral to the left deviated to the left; and when I took an equal weight of each of the two kinds of crystals, the mixed solution was indifferent toward the light in consequence of the neutralization of the two equal and opposite individual deviations.

Pasteur gives us evidence at this point of that intense curiosity concerning nature's secrets without which no one becomes a scien-

ıst. He rushed out of the room and, finding a curator, embraced him and cried, "I have just made a great discovery; I am so happy I am trembling so I can hardly put my eye to the polariscope again." Some years after he said, "The study of these acids is of ımmense interest. I do not know any that is more interesting." A very different object of interest, you will admit, from those which arouse the ordinary mind.

The first to appreciate the significance of Pasteur's discovery was naturally Biot, who with his own hands tested crystals which Pasteur obtained in his presence. When the result was achieved the old man in his enthusiasm took Pasteur by the arm and said, "My boy, I have loved science so much throughout my life that this makes my heart throb."

Pasteur was but 26 when he made this discovery. It at once brought him into prominence in the scientific world. His further studies included two further methods for separating such asymmetric substances from each other. One consisted in the combination of the acid with a naturally occurring optically active base, giving rise to two salts which now no longer rotated in opposite directions to an equal extent, and which therefore were no longer identical in other respects, so that they can be separated by fractional crystallization. The other method resulted from the discovery that a certain ferment would destroy one of these acids in the racemic mixture, paratartaric acid, leaving the other unchanged. This work with ferments was the opening door to most of his later work in the field of biology. These methods for separating optically substances are to-day the only ones which we possess.

Pasteur further called attention to a problem which still remains one of absorbing scientific interest. Whenever asymmetric substances are prepared in the laboratory from inactive substances, the chance rearrangement of atoms favors neither the right nor the left-hand form, so that the result is always a racemic mixture, composed of right and left-handed forms in equal amount. Nature, however, for some reason still unknown to us, is able to produce a single form, such as dextro-rotatory cane sugar and spiral bacteria all twisted in the same direction. The explanation of this extraordinary fact has yet to be furnished.

Pasteur discovered still another form of tartaric acid, inactive, like the racemic mixture of dextro and laevo forms, but this time because the molecule is *internally* compensated, one end being right-handed, the other left-handed. He also indicated the probable arrangement of the atoms in the molecules to account for the various forms discovered. These ideas were further developed independently by Le Bel, in France, and by van 't Hoff in Holland, and

have finally given us very definite evidence concerning the spatial arrangement of atoms in molecules.

I shall endeavor to explain this arrangement for the tartaric acids by the aid of models.

You are doubtless inclined to consider a discovery of this sort as of academic interest only, and of far less importance to mankind than the later work of Pasteur. May I, therefore, point out the fundamental importance to human welfare of the knowledge of the constitution of chemical molecules; a knowledge which has enabled us, like architects, to draw plans of molecules and to lop off or add or substitute parts of these molecules in order to attain a desired result. The artificial synthesis of a host of natural products and of products which in many cases are improvements upon those of nature rests upon knowledge gained in part through this important work of Pasteur.

May I call your attention in this connection to the words of Pasteur himself, who, with his customary deep insight, said:

> Without theory practice is but routine born of habit. Theory alone can bring forth and develop the spirit of invention. It is to you specially that it will belong not to share the opinion of those narrow minds who disdain everything in science which has not an immediate application. You know Franklin's charming saying? He was witnessing the first demonstration of a purely scientific discovery, and people around him said: "But what is the use of it?" Franklin answered them: "What is the use of a new-born child?" Yes, gentlemen, what is the use of a new-born child? And yet, perhaps, at that tender age, germs already existed in you of the talents which distinguish you! In your baby boys, fragile beings as they are, there are incipient magistrates, scientists, heroes as valiant as those who are now covering themselves with glory under the walls of Sebastopol. And thus, gentlemen, a theoretical discovery has but the merit of its existence; it awakens hope, and that is all. But let it be cultivated, let it grow, and you will see what it will become.
>
> Do you know when it first saw the light, this electric telegraph, one of the most marvelous applications of modern science? It was in that memorable year, 1822: Oersted, a Danish physicist, held in his hands a piece of copper wire, joined by its extremities to the two poles of a Volta pile. On his table was a magnetized needle on its pivot, and he suddenly saw *(by chance, you will say, but chance only favors the mind which is prepared)* the needle move and take up a position quite different from the one assigned to it by terrestrial magnetism. A wire carrying an electric current deviates a magnetized needle from its position. That, gentlemen, was the birth of the modern telegraph. Franklin's interlocutor might well have said when the needle moved: "But what is the use of that?" And yet that discovery was barely twenty years old when it produced by its application the almost supernatural effects of the electric telegraph!

How much more we can add to-day to the list of fruits of this discovery: the dynamo, the electric motor, the electric light, the trolley car, the telephone, vanadium steel, carborundum, artificial graphite and a host of others, all made possible by this one discov-

ery! And such for chemistry was the discovery I have just outlined. Of what use was it? Of more use than all of the work of European politicians together in the year 1848!

I may be permitted, in closing, to refer briefly to another fruit of the life of Pasteur. Science is sometimes reproached as contributing only to the material well-being of mankind. I would assert on the contrary and with all boldness that nothing could be farther from the truth. Science has made a spiritual contribution of the utmost value, and in many respects unique. This contribution has been superlatively illustrated in the life and character of Pasteur. No one, I imagine, can read his life without being impressed by his constant, conscientious, unselfish devotion to the pursuit of truth; not the conception of truth which for ages has cursed mankind, which is represented by tradition and dogma, whose extension is sought by the method of the Inquisition, by stifling freedom of thought and inquiry; but rather the truth as determined by the scientific method of carefully questioning Nature, and honestly, eagerly and intelligently interpreting her responses. This is the only method for the discovery of truth which has shown itself abundantly able to yield the truth.

We see Pasteur pursuing this quest now in one realm, now in another, but always with a pressing sense of duty which allows him no respite even upon the sickbed; which prevents him from pausing to gather wealth from the consequences of his labors, although, as Huxley said, he created wealth for France which more than sufficed to pay the German indemnity. Here was a man who will long serve as an inspiration to those who try to follow the same quest. The world is far richer spiritually, as well as materially, from his presence.

His own words in closing a lecture upon molecular asymmetry serve as a fitting close to these words of mine:

> Such, gentlemen, are in coordinated form the investigations which I have been asked to present to you.
>
> You have understood, as we proceeded, why I entitled my exposition, "On the Molecular Asymmetry of Natural Organic Products." It is, in fact, the theory of molecular asymmetry that we have just established, one of the most exalted chapters of the science. It was completely unforeseen, and opens to physiology new horizons, distant, but sure.
>
> I hold this opinion of the results of my own work without allowing any of the vanity of the discoverer to mingle in the expression of my thought. May it please God that personal matters may never be possible at this desk. These are like pages in the history of chemistry which we write successively with that feeling of dignity which the true love of science always inspires.

Pasteur and the Science of Bacteriology

By Professor J. G. FITZGERALD, M.D., F.R.S.C.
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AN account of the work of Pasteur in the field of bacteriology requires to be prefaced by the observation that prior to his time the foundations of this science had not been laid. To very few men is given the opportunity of charting the course, however roughly, of a new branch of science in the immense ocean of the unknown. Still fewer possess the unconquerable spirit and the genius to strike out boldly and surely, and to reach the haven of immense achievement and solid and enduring contribution to science and human welfare. This, however, was the destiny of Pasteur, and to-day, one hundred years after his birth, and nearly twenty-eight years after his death, he is in even the most remote corners of the world being acclaimed as one of the greatest benefactors of humanity who has ever lived.

Pasteur's preliminary scientific training was very broad and thorough. He took immense pains to acquire a substantial background of mathematics and the natural sciences, physics, chemistry and biology. There was, of course, very much less differentiation of and distinction between these three branches of natural science seventy-five years ago. It was quite possible for a scholar of that time to become an authority in all three fields, to keep abreast of new developments and at the same time to make substantial contributions to all of them.

Pasteur's earliest work was in the field of chemistry. Between 1845 and 1855 his attention was directed almost entirely to the solution of problems which were only indirectly related to biology and to bacteriology. His studies in stereochemistry and subsequently in fermentation proved to be the bridge over which he crossed to enter the realm of bacteriology. The authority of the great chemists Berzelius and Liebig was such at this time that their theories of the nature of fermentation were everywhere accepted. Liebig's explanation of chemical decomposition or fermentation was that a ferment or influence (this being an unstable organic substance) in decomposing set in motion, as a result of the rupture of its own elements, the loosely bound molecules of the fermentable matter. In other words, the part of the yeast which produced fermentation was an altered, dead portion, acting upon sugar. According to this it was not the result of vital activity; in other

words, it was not a physiological process. Pasteur, as was his invariable custom, submitted the question to experimentation. Through scientific investigation he felt convinced this problem could be solved and in no other way. Fruitless speculation had too long delayed the elucidation of the question. Pasteur was at this time, 1856, professor and dean of the Faculté des Sciences at Lille. Here many opportunities for the study and investigation of the processes of fermentation presented themselves.

He examined with his microscope the fluids in which fermentation was proceeding. He observed the shape of the living micro-organisms in these fluids. He correlated his microscopic findings with the results obtained on many occasions in the process of fermentation with different fluids containing a variety of micro-organisms. Pasteur established the fact that when certain micro-organisms were present the fermentative changes resulted in the recovery of satisfactory products; when other forms were present, the contrary was the case. Schwann and Cagniard-Latour, the latter a French physicist of distinction, had prior to this time observed that the ferment was composed of yeast cells and that they reproduced by budding. They also speculated that these yeast cells probably acted upon sugar through some effect of their vegetation. Pasteur continued his experiments on both lactic acid and alcoholic fermentation and soon he had convinced himself that fermentation of any sort was due to the activities of a living micro-organism. He found that different types of fermentation were due to different varieties of these micro-organisms. In this, as in other investigations, Pasteur presented the results of adequate and carefully controlled experiments, where others had been satisfied with a few observations and much speculation. The paper on lactic acid fermentation was presented before the Lille Scientific Society in August, 1857. Later during the same year a paper on alcoholic fermentation was read before the Académie des Sciences in which he declared that his experiments showed that the splitting of sugar into alcohol and carbonic acid was due to the activities of organized living agents, "microscopic globules." It was a physiological process.

These were the first correlated studies of morphology and biochemical activities of bacteria ever made and were completed at a time when there was no technique for the isolation of bacteria in pure culture, no methods of sterilization and no definite criteria for the differentiation of bacterial species. Parenthetically, it may be added, it was also prior to the time when any bacterial species had indubitably been shown to be the etiological agent of a disease process in man or lower animals.

At this time a firm belief in spontaneous generation (generatio aequivoca) was not the exclusive possession of children, pseudo-philosophers or the illiterate. On the contrary it was very widely held. The doctrine, "omne vivum e vivo" or "omne vivum ex ovo," while strongly supported by the earlier work of Spallanzani had many more enemies than friends. For the next five years (1765) Pasteur devoted himself assiduously to scientific experimentation aimed at the elucidation of this problem as well as continuing his studies of fermentation and putrefaction. In 1861 in conducting experiments on butyric acid fermentation Pasteur made the very fundamental observation that certain micro-organisms developed only in the absence of free oxygen. Thus the first discovery relating to anaerobiosis as well as the varying oxygen requirements of different bacteria was made.

In the meantime a very bitter scientific controversy was being waged about the question of spontaneous generation—several scientific workers in France as well as others elsewhere were not disposed to admit that Pasteur was right when he concluded as a result of a long series of experiments that the appearance of living micro-organisms in fluid contained in flasks, etc., was due to the contamination of the fluid by air containing organized bodies.

Infusions of organic matter were made. They were clear when first prepared. They were then exposed to heat, even to boiling. Unless carefully protected from dust particles they soon became cloudy and if examined were found to contain innumerable micro-organisms. Pasteur's own words quite explicitly and concisely indicate how he once and for all disposed of the question of spontaneous generation. He wrote:

> I place a portion of that infusion into a flask with a long neck, like this one. Suppose I boil the liquid and leave it to cool. After a few days, mouldiness or animalculae will develop in the liquid. By boiling, I destroy any germs contained in the liquid or against the glass; but that infusion being again in contact with air, it becomes altered, as all infusions do. Now suppose I repeat this experiment, but, before boiling the liquid, I draw (by means of an enameller's lamp) the neck of the flask into a point, leaving, however, its extremity open. This being done, I boil the liquid in the flask and leave it to cool. Now the liquid of this second flask will remain pure not only for two days, a month, a year, but three or four years—for the experiment I am telling you about is already four years old, and the liquid remains as limpid as distilled water. What difference is there, then, between those two flasks? They contain the same liquid, they both contain air, both are open! Why does one decay and the other remain pure? The only difference between them is this: in the first case, the dusts suspended in air and their germs can fall into the neck of the flask and arrive into contact with the liquid, where they find appropriate food and develop; thence microscopic beings. In the second flask, on the contrary, it is impossible, or at least extremely difficult, unless the air is violently shaken, that dusts suspended in air should enter the flask; they fall on its curved neck.

When air goes in and out of the flask through diffusions or variations of temperature, the latter never being sudden, the air comes in slowly enough to drop the dusts and germs that it carries at the opening of the neck or in the first curves.

This experiment is full of instruction; for this must be noted, that everything in air, save its dust, can easily enter the flask and come into contact with the liquid. Imagine what you choose in the air—electricity, magnetism, ozone, unknown forces even, all can reach the infusion. Only one thing cannot enter easily, and that is dust, suspended in air. And the proof of this is, that if I shake the flask violently two or three times in a few days it contains animalculae or mouldiness. Why? Because air has come in violently enough to carry dust with it.

And, therefore, gentlemen, I could point to that liquid and say to you, I have taken my drop of water from the immensity of creation, and I have taken it full of the elements appropriated to the development of inferior beings. And I wait, I watch, I question it, begging it to recommence for me the beautiful spectacle of the first creation. But it is dumb, dumb since these experiments were begun several years ago; it is dumb because I have kept it from the only thing man can not produce, from the germs which float in the air, from Life, for Life is a germ and a germ is Life. Never will the doctrine of spontaneous generation recover from the mortal blow of this simple experiment.

Pasteur's work on fermentation was a logical preliminary to his attempt in 1864 to determine the cause of the disease of wines which entailed very considerable economic losses in certain districts in France. He concluded after careful morphological studies of the micro-organisms found in the wines that "the alterations of wines are co-existent with the presence and multiplication of microscopic vegetations." Certain concrete proposals were made by Pasteur at this time, which, had they been adopted, would have controlled the undesirable fermentative activities in wines. The thermal death point of these micro-organisms was ascertained very definitely. These were the first accurate experimental studies of thermal death points of bacteria. Between the years 1865 and 1870 Pasteur was engaged in a series of investigations in an effort to discover the cause of an epidemic which was ravaging the silkworms and threatening the very life of sericulture in France. This fascinating chapter of achievement properly belongs in the category of work in protozoology and so will not be dealt with here.

We have now reached the place in Pasteur's scientific life where he was about to scale the heights and to achieve enduring fame. The philosophic conception that certain human and animal diseases which manifested pronounced communicability and appeared in pandemic or epidemic outbursts were really due to living agents or "contagium vivum" was expounded at regular intervals. About 1666 Robert Boyle, an English physicist at Oxford, had expressed the conviction that the solution of the problem of the nature of ferments would do much to explain certain phenomena of disease.

Pasteur was very greatly impressed by this and in his mind's eye saw clearly the possible relationship of minute living agents to communicable diseases. But vague speculation was to have no place in the program which Pasteur marked out to test the validity of this conception. Accurate and careful observation, correlated with splendidly conceived and wisely controlled experiment, was alone depended upon to reveal the truth.

The work in 1871 on cultures of yeasts of value in brewing led to the development of an exact technique for sterilization, the so-called method of pasteurization or fractional sterilization. This added much to the methodology of the embryonic science of bacteriology. In 1874, before the etiological relationship of any bacterial species to a disease process had been conclusively established, Joseph Lister, later Lord Lister, a Scottish surgeon, who had read and profited by Pasteur's work on lactic acid fermentation, wrote to Pasteur as follows:

My dear Sir—Allow me to beg your acceptance of the pamphlet, which I send by the same post, containing an account of some investigations into the subject which you have done so much to elucidate, the germ theory of fermentative changes. I flatter myself that you may read with some interest what I have written on the organism which you were the first to describe in your "Memoire sur la fermentation appelée lactique."

I do not know whether the "Records of British Surgery" ever meet your eye. If so, you will have seen from time to time notices of the antiseptic system of treatment, which I have been laboring for the last nine years to bring to perfection.

Allow me to take this opportunity to tender you my most cordial thanks for having, by your brilliant researches, demonstrated to me the truth of the germ theory of putrefaction, and thus furnished me with the principle upon which alone the antiseptic system can be carried out. Should you at any time visit Edinburgh, it would, I believe, give you sincere gratification to see at our hospital how largely mankind is being benefited by your labors.

I need hardly add that it would afford me the highest gratification to show you how greatly surgery is indebted to you.

Forgive the freedom with which a common love of science inspires me, and

Believe me, with profound respect,

Yours very sincerely,

JOSEPH LISTER

The foundations, first, of antiseptic and later of aseptic surgery were thus laid by Pasteur. He at this time very definitely advised the sterilization of all surgical instruments before use by passing them through a living flame and he also recommended the sterilization of all surgical dressings by heating to a temperature of 150° C. before being used. He also proposed that plugs of cotton wool should be used to stopper glass vessels containing sterile fluids to prevent the entrance of organic matter containing living micro-organisms.

In 1838 Delafond, of the Alfort Veterinary College, saw in the blood of cattle that had died of anthrax "little rods" to which he attached no significance. In 1850 Davaine and Royer repeated the work of Delafond but without appreciating its significance. Davaine in 1863 read Pasteur's paper on (the cause of) butyric acid fermentation and was greatly impressed by it, and in 1863 he again examined the blood from sheep that had died of anthrax and found in it tiny bodies which he called "bacteridia." He announced that he believed these were the cause of anthrax. Various workers now took up the question and very soon the whole subject was completely obscured by contradictory and conflicting results.

Pasteur undertook to investigate the question. He took a small amount of blood from an animal that had died of anthrax, and with all aseptic precautions planted it in a sterile flask containing a slightly alkaline, sterile culture medium. In this medium he grew pure (single) cultures of anthrax bacilli. He noted the characteristic growth of these micro-organisms. He subcultured his growths by carrying over from flasks in which the bacilli were growing a few drops to other flasks of sterile culture medium, thus seeding them and permitting new generations of these microbes to appear.

The next step consisted in establishing that the germs which were thus grown in an artificial culture medium were really the causative agents of the disease anthrax. This was done by the injection into susceptible animals of a drop of culture material from the flasks. The animals so injected developed anthrax and from their blood anthrax bacilli were recovered. Thus the etiological relationship of a species of micro-organism to the disease anthrax was conclusively established. The way was now prepared for the complete investigation, through the application of similar methods, of all the communicable diseases. Pasteur announced it as his belief that "each infectious disease is produced by the development within the organism of a special microbe." Between 1877, when Pasteur completed his work on anthrax, and 1895, the year of his death, the causative agents of nearly all the important communicable diseases were discovered.

To this very remarkable accomplishment Pasteur contributed the lion's share in elaborating technical procedures, formulating criteria by which results could be appraised and by a rigid insistence on the necessity for most exact experimental verification of all opinions expressed or views advanced. Such remarkable achievements would in the vast majority of cases have marked the climax of scientific contribution. Such, however, was not the case with Pasteur. His great vision led him to develop specific methods of inestimable benefit to the human race for the prevention of many communicable diseases.

In all of this he was guided by ideals which were embodied in the declaration, "Blessed is he who carries within himself a God, an ideal, and who obeys it; ideal of art, ideal of science, ideal of the gospel virtues, therein lie the springs of great thoughts and great actions; they all reflect light from the Infinite." In no small measure the improvements noted in the state of the public health in the last two decades in the United States as elsewhere are the fruits of Pasteur's labors. Thus through the application of the methods of preventive medicine in the past fifty years in this country the span of life on the average has increased 15 years, forty-one years being the average length of life in 1870, whereas it was 56 in 1920. In the past twenty years also the infant mortality rate has been reduced one third, the tuberculosis death-rate cut in half and the deaths from typhoid fever reduced to one fifth of their former number. These are some of the reasons why a grateful posterity should pause to pay homage to the memory of Louis Pasteur.

Pasteur and the Science of Medicine

By Professor W. P. LUCAS, M.D.
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SOME one has said of Pasteur "that he did more than make discoveries; he discovered how to make them." In his long fight to convince the medical profession of the value that lay in the discoveries he had made as a chemist in the laboratory, he constantly stressed the point that such discoveries as had come from his studies of fermentations, of so-called spontaneous generation, of silkworm diseases, splenic fever, chicken cholera and the rest were but the establishment of methods which would lead to a new world of medicine. Bitter hostility came to him—how dared this chemist, successful as he might be in the protection from disease of silkworms and sheep, suppose that the field of medicine, about which he knew nothing, could accept his conclusions that struck at the very roots of the traditional dogmas of their profession? But hostility never made Pasteur hostile. He invited his enemies into his laboratory and with a divine patience demonstrated the methods by which his conclusions were reached.

In speaking one day to a group of students in the Medical Academy, who sat before him in varying moods of hostility, indifference and scepticism, his deep voice rang out a challenge, "Young men, you who sit on these benches, and who are perhaps the hope of the

medical future of the country, do not come here to seek the excitement of polemics, but come and learn method."

In all the struggle, he never asked medical men to believe in him but to believe in the methods which were being established by actual proofs which could be demonstrated to the open mind. The stories of the conflicts which he had all reveal the openness of his own mind, his desire for criticism, his honest search for truth in the field of science. Hurrying into a lecture one day on a subject new and full of infinite possibilities, he said to one of his men: "Do repeat to me every criticism you hear. I much prefer them to praise, barren unless encouragement is wanted, which is certainly not my case. I have a lasting provision of faith and fire." As he said another time, full of that faith and fire, "The breath of Truth is carrying medicine toward the fruitful fields of the future."

As Vallery-Radot says of him, "He had that intuition which makes a great poet out of a great scientist." In the story of his life from beginning to end these two souls, the poet and the scientist, walked side by side. Every discovery made in the laboratory was always accompanied by a flash of light, as it were, which would reveal to him for a moment the next field far ahead. But he never credited himself with anything but the capacity for hard work. In speaking to some students, he said "that it was through assiduous work, with no special gift but that of perseverance joined to an attraction towards all that is great and good, that he had met with success in his researches." The scientist, Pasteur, kept the poet, Pasteur, well in hand. He insisted always upon experimental proofs—whatever that flash of light had revealed to him, he knew there was but one way to convince others and that way was the way of experimental method. Nothing irritated him more than the slightest error in reporting results, or fulsome praise of him that claimed more than had been proved.

In the attempt in a few moments to pay a tribute to Louis Pasteur's contribution to medicine, I am glad that the bacteriologist, the chemist, the protozoologists have spoken and have given you the picture of that chemist whom the medical profession of the day were sometimes bitterly reluctant to accept as a co-worker in the field devoted to the preservation of human life. As Duclaux, the director of the Pasteur Institute, upon Pasteur's death said: "We see also that the physicians were right in treating him as a chemist. They were wrong only in pronouncing this name with a disdainful air. With Pasteur, chemistry took possession of medicine and we can foresee that it will not relinquish its hold."

Surgery extended the first warm welcome to Pasteur and his revelation of "The kingdom of infinitely small things" brought to

that great surgeon Lister the weapon he needed in his fight for antisepsis and asepsis. Lister had been following closely Pasteur's studies in fermentation and when Pasteur proved in 1865 that putrefaction was a fermentation caused by the growth of microbes and these could not arise de novo in the decomposable substance, Lister had, at last, firm ground under his feet, in fighting the scourge of surgery, putrefaction in open wounds. Surgery up to this time had been a ghastly arena of suppurating wounds. Now germs must be killed and no more must be allowed to get into the wound. What Pasteur demonstrated in filtered air in flasks, Lister worked out for the man with a dirty lacerated wound. The truth of the germ theory of putrefaction led to the final success of the antiseptic system Lister had worked over for years. It must have been a great moment to have shared in when years later, on Pasteur's seventieth birthday, the great English surgeon stood in the crowded amphitheater of the Sorbonne and, representing the Royal Academy of London and the Royal Society of Edinburgh, brought to Pasteur the homage of medicine and surgery.

"Truly," said Lister, "there does not exist in the whole world an individual to whom medical science owes more than to you. Your researches on fermentations threw a powerful light which has illuminated the dark places in surgery and has changed the treatment of wounds from an uncertain, emperic and too often disastrous business into a scientific and certainly beneficial art. Thanks to you, surgery has undergone a complete revolution which has deprived it of all its terrors and which has increased its efficacy to an almost unlimited extent."

In October 19, 1868, Pasteur at the age of 46, in the final work on the diseases of the silkworm, suffered a stroke of paralysis. His life was despaired of—at least all idea of active, productive life was over, many thought. Work was stopped upon his precious chemical laboratory to be built by the state because the general feeling was that without Pasteur such a laboratory was an unnecessary investment of money. He had made as yet no direct contribu tion to medicine. English surgery was profiting, but French surgery still scoffed at the germ theory. Pasteur at first thought he was doomed to die, but slowly that indomitable spirit and clear mind fought its way back to productivity and from 1868 to 1880 he laid the foundation stones of modern medicine. To be sure, it was anthrax, chicken cholera, swine fever, the working out of the protective treatment on animals to which he gave his strength, but by 1880 he had discovered how to attenuate the virus of chicken cholera—in another year he knew how to intensify the virus of anthrax by inoculating with an attenuated virus a series of newly born guinea pigs.

To be able to bring down a virus step by step from full virulence to non-virulence—to be able also to exalt a virus step by step from non-virulence to full virulence, he was able to obtain his standard virus—to measure the exact strength of a virus and to calculate the exact effect upon an animal. So with graduated series of attenuations of the virus, he was able to confer immunity against the disease itself. But it was five years before he took the final step from animal to man, and the terrible scourge of hydrophobia or rabies common to Europe at that time determined him to make his first effort there. Rabies was always fatal, and to the mind and heart of Pasteur, whose kindness was a living flame, it made his final step easier to attack a disease from which there were no known recoveries.

The experiments with the saliva of mad dogs were thrilling and dangerous—but Pasteur knew no fear of that kind. Perhaps his first real fear was in the presence of Joseph Meister, the little boy of nine, terribly bitten by a mad dog, who was brought to him July 6, 1885, by a poor frightened mother from Alsace. The story of that first trial to save a human life should be read by all. The tender anxiety of Pasteur, the sleepless nights, the anguish of fear that the child would die, the gradual realization that the truth of his laboratory experiments had been convincingly proved brought a joy to Pasteur no words can describe. The future would see, as Lister said, the veil raised which for years had covered infectious diseases. The question of the return of virulence is, Pasteur declared, of the greatest interest for the etiology of contagious diseases. The attenuation and reinforcement of virus have been the guiding stars of modern medicine. Three years after little Joseph Meister recovered, in 1888 the great Pasteur Institute at Paris was opened and Pasteur entered, "a man vanquished by time" as he said, because of increasing age from heavy work, but the light had constantly flashed from his tireless brain and spirit. He was convinced that diphtheria, typhoid, cholera, yellow fever could all be conquered. He would not live to see it, but upon his work it has all been accomplished. It had taken him thirty years to establish just three scientific conceptions of undreamed-of service to medicine: *First,* each fermentation is produced by the development within the organism of a special microbe; *second,* each infectious disease is produced by development within the organism of a special microbe; *third,* the microbe of an infectious disease cultivated under certain detrimental conditions is attenuated in its pathogenic activity; from a virus it becomes a vaccine.

From that *first* conception, the rules developed which govern our present-day pasteurization, known and practiced in the ordinary life of households and industries the world over.

From the *second*, as we have said, Lister drew to completion his system of surgical antisepsis, puerperal fever was vanquished and child life saved and modern surgery made more nearly an exact science.

The *third* conception, upon which Pasteur based his antirabic serum, prevents hydrophobia and is the fundamental conception underlying all the achievements for tuberculosis, plague, malta fever, malaria, tetanus, cerebro-spinal fever. The work on epidemic infantile paralysis, the work of Metchnikoff on arterio-sclerosis, of Ehrlich on syphilis, on leprosy, dysentery, sleeping sickness, have all been built upon the germ theory and the method of dealing with micro-organisms which Pasteur worked out. Diphtheria is now a preventable disease, its mortality reduced from 50 to 60 per cent. to 2 per cent. Mortality from rabies is less than 1 per cent.

Once in answering an attack upon his theory of fermentation, he said: "You wish to upset what you call my theory in order to defend another. Very well, let me tell you the signs by which a theory may be recognized as true. The characteristic of erroneous theories is that they can never produce new facts, and every time that a fact of this kind is discovered, these theories are obliged, in order to account for it, to graft a new hypothesis on to the old one. The characteristic of true theories is, on the contrary, to be the expression of actual facts, to be ruled and dominated by them, to be able to foretell new facts with certainty—in a word, the characteristic of these theories is their fertility."

We are glad Pasteur lived to see thousands of children saved by diphtheria antitoxin, and knowing the tender heart of the great man, it must have been the consolation of his feebler years. "When I see a child," he used to say, "he inspires me with two feelings, tenderness for what he is now—respect for what he may become hereafter." And so Louis Pasteur brought to medicine methods of research whose fertility knows as yet no limitation but time, the characteristic, as he said, of true theories. Modern sanitation, modern hygiene, modern preventive medicine are based fundamentally upon Pasteur's theories.

"He was not a doctor, he did not cure individuals, he only tried to cure humanity," was an explanation given of him by one who loved him. He brought more than method and proved theory to modern medicine, he brought the spirit of scientific investigation, the impersonal search for truth, a passion for service, an honest welcome to honest criticism. "Worship, the spirit of criticism," he said, "if reduced to itself, it is not an awakener of ideas or a stimulant to great things but without it, everything is fallible, it

always has the last word. When you believe you have found an important scientific fact, and are feverishly anxious to publish it, constrain yourself for days, weeks, years sometimes, fight yourself, try and ruin your own experiments and only proclaim your discovery after having exhausted all contrary hypothesis. But when, after so many efforts you have at last arrived at a certainty, your joy is one of the greatest which can be felt by a human soul."

In his last public address, he refers to himself as "a man whose invincible belief is that science and peace will triumph over ignorance and war, that nations will unite, not to destroy but to build and that the future will belong to those who will have done most for suffering humanity. But whether our efforts are or are not favored by life, let us be able to say, when we come near the great goal, 'I have done what I could.'"

In the quiet low-vaulted chapel at one end of the long corridors of the Pasteur Institute in Paris, Pasteur lies. Four great white angels guard his sleep, Faith, Hope, Love and Science. As war once more devastated his beloved country and nations were once more united to destroy, one was glad that Louis Pasteur, who gave his life to constructive forces, was spared the agony of the struggle. And yet by his efforts the horrors of that struggle were lessened and the future still belonged to Louis Pasteur, who had done most for suffering humanity.

BOTANICAL FACILITIES IN PARIS

By Dr. ORAN RABER
UNIVERSITY OF WISCONSIN

THE time has passed when it was impossible for a man to obtain a place in a first-class American university without a European degree. Our equipment, our facilities for research and our scholars are not excelled in any of the institutions of Europe; and, although for a few special fields there may be exceptional attractions abroad, the American university has become of age. It is quite able to take care of itself freed from European tutelage.

As long as personality, however, has any influence in this world and until all parts of the earth become so similar in conventions and customs that travel will have lost its charm, there will be men who, in spite of the inducements of better laboratory facilities, in spite of the comparatively great wealth of our own universities, and in spite of the inconveniences of foreign languages and habits, will travel to distant lands to complete or supplement their education.

And this is as it should be. In the middle ages a certain amount of travel was considered indispensable to the training of the educated gentleman, and from that day to this there has been fostered this spirit of international exchange of ideas. The Great War for four years deterred the natural flow of student life and turned aside the stream into other channels. Soldiers instead of students formed the mass of the current and increased its dimensions many-fold. And now that the war is over and the world again is turning to the arts of peace, many of these same students, their interest awakened by the contacts made in the days of 1918, are planning to return and reexplore the countries in which they fought. This time they are going back with books instead of bayonets and scalpels instead of swords.

Because of the French connections made and interests aroused during the war, France in place of Germany will be the natural goal of this new army. Paris at the moment has more interest than Berlin. Furthermore, France has now made it possible for a foreigner to secure the doctorate, and those individuals who can not work without the stimulus of the Ph.D. or Sc.D. to lure them on can now find in France the way to satisfy their ambition.

All France is divided into two parts—Paris and the Provinces. While the provincial universities have facilities which in many cases equal those in the capital, the many-sided life of Paris is certain to attract every student there sooner or later, and, supposing, as we are in this case, that the student is a botanist, what and whom is he going to find there once he has arrived? What are the botanical facilities in Paris and who are the botanists that at the present time are directing the botanical life of the famous city? In the following pages it is attempted to summarize in a concise fashion the equipment, including libraries and herbaria, and to give the prospective student an idea of the personalities who are conducting the research laboratories, with a brief survey of the personal interests of the investigators in charge, the number of graduate students in the laboratories and as much as possible of the sort of information which one likes to know before entering any particular laboratory or institution.

The institutions of higher learning in Paris where research facilities are provided in Botany are École Normale, l'Institut Pasteur, Museum d'Histoire Naturelle and La Sorbonne or the University of Paris, with its Faculty of Pharmacy and Faculty of Science. It will be noted that the Collège de France is not in this list. It possesses no chair of botany and it is hence impossible to receive either botanical instruction or carry on botanical researches there.

Of these four institutions the Normal School and the Pasteur Institute may be considered together. Both research laboratories in botany are under the supervision of Professor Blaringhem. The teaching phases of the subject are handled at the Normal School, while the research work is conducted at the Institute. If any thesis prepared is submitted for a degree it is presented through Blaringhem to the Sorbonne, which awards the degree, since neither the Institute nor the Normal School have the power to grant the doctorate. Only a university can grant degrees, but other institutions can train research workers. The theses are examined by a committee of the Sorbonne in conjunction with the professors of the collaborating institution.

In addition to these two laboratories under the supervision of Blaringhem there is a field station at Bellevue, out ten kilometers from Paris, and a laboratory for the study of forestry and the acclimatization of trees at Angers. With these varied interests Professor Blaringhem is a busy man. He has a bit too much for one man to handle but, in spite of this handicap, students from America who wish to enter his laboratory will be very welcome. He is assisted by an instructor at the Normal School and has one

laboratory assistant at the Institute. There is also an assistant in charge at Bellevue. The time of all these assistants is at the disposal of graduate students.

During 1921–1922 there were three students working for the doctorate. One was working on some phase of physiology connected with plant breeding, a second on the cause of striped leaves and leaf spot, and the third on variations in the violets. These subjects are noted, since they may serve to the prospective student as a guide to the interests of the professor in charge. Blaringhem's special field is the study of heredity and variations.

The library at the Normal School is especially rich in books dealing with the cryptogams. The herbarium at the Normal School is not in good condition for research, but at the Institute there is a herbarium of about 60,000 sheets, covering France and the Mediterranean region. This herbarium is a selected one made for the purpose of showing variations.

Le Museum au Jardin des Plantes

The museum is not a teaching institution in the regular sense, since no courses are given which lead to diplomas or degrees, although there are many lectures open to the public, and free courses somewhat in the nature of our extension courses are given. It is open to every one free of charge. There are no degrees granted, and in this respect it is similar to the Pasteur Institute. Work completed there may be turned in as a thesis to the committee of the Sorbonne.

The activities of the museum correspond to the biological phases of the work done by the British Museum. In America we have nothing which corresponds to it, although the Smithsonian Institution and the Department of Agriculture at Washington are perhaps the nearest analogies. At the present time the building in which the botanical collections are housed is antiquated and inadequate. The laboratories are only fairly well lighted and the general facilities are poor. In the near future, however, a new building is to be built which will be more adequate to the demands of the collections.

In botany research is carried on in five different lines with a competent researcher in charge of each section. These men are Mangin, Bois, Costantin, LeCompte and Maquenne.

Professor Mangin, who is one of the six botanists in the Academy, is at the present time the director of the museum and at the same time is in charge of the research work in the Thallophytes and Bryophytes or cellular cryptogams. His special fields are the parasitic fungi and plankton. Foreigners are very welcome in his

laboratory and he will do everything possible to put before them the facilities of the museum. In his laboratory there are three assistants, which include the herbarium aides.

The library contains about 3,500 volumes on Algae and about 2,000 on the Fungi, including separates. There is a general herbarium and also several individual herbaria, coming from private collections, which make a very complete collection of Algae, Fungi and Bryophytes. The Algae collection is among the most complete in Europe.

Professor Bois has charge of the greenhouses and supervises the culture of the plants in the garden. He gives a public course on the culture of plants with especial reference to decorative species and also makes field trips. He was a student of deVries and it is not surprising that his special field is variation and heredity.

Professor Costantin is a member of the Academy and professor of morphology and paleobotany. His special field is organography and his principal researches have been on the effect of environment on plants and on the culture of Fungi.

In his laboratory he has one assistant and two preparateurs (a rank which corresponds to that of an instructor in a university) who assist him and any other workers present. At the present time he also has with him a Museum Fellow who is working upon the effect of Alpine climate upon floral structures. The library connected with this laboratory contains about 2,500 volumes.

Professor LeCompte is also a member of the Academy and is in charge of systematic botany with special reference to the vascular plants. The herbarium is the largest in France, as the following figures attest:

	Sheets.	Species.
Phanerogams	1,500,000	85,000
Vascular cryptogams	50,000	2,000

LeCompte gives all assistance possible to the many workers who arrive daily to consult the herbarium, and in addition the services of the seven assistants are at their disposal.

The chief researches of Professor LeCompte have been made upon the phloem of angiosperms, floral articulations and the woods of the French colonies. At present he is engaged upon the flora of Indo-China.

The library of systematic botany is very complete. There are 10,000 cards in the index, and in addition the cards of the other libraries of the museum are indexed in the systematic catalog. This figure includes the separates.

This laboratory collaborates very closely with that of Professor Costantin, in which latter laboratory the more characteristically morphological studies are made.

Professor Maquenne is in charge of physiology and is interested chiefly in the action of salts, respiration and the action of the ultra-violet rays. Professor Maquenne is a member of the Academy, but not of the botanical section. Because of the practical application of his work to agriculture he has been admitted to the section of applied sciences. Among the laboratories at the museum the writer recommends least that of Maquenne. As described below there are other laboratories in Paris open for researchers in physiology where foreign workers will receive a more cordial welcome. Furthermore, Professor Maquenne is growing old, and this fact, coupled with increasing deafness, detracts from the enthusiasm of the foreign student regardless of the excellent work which Professor Maquenne has done in the past.

The Sorbonne

Since the thirteenth century, when the University of Paris was founded, workers have been drawn from all over the civilized world to its laboratories and lecture halls. It is the most famous institution of higher learning in all France, and it is fitting that it should here be reserved for the end of these brief remarks.

There are two "faculties" or colleges in which botanical training is given, *viz.*, the college of pharmacy and the college of science. The School of Pharmacy is a purely professional school, and the work taken in course leads to the degree of doctor of pharmacy. By special arrangement, however, it is possible for a graduate student to do research in the laboratories of this school and take the degree of doctor of science.

Professor Guignard has charge of the work in phanerogams and finds little time for the supervision of research students. He would accept American research students only by previous arrangement, so that it would not be advisable for a student to make plans for entering his laboratory without going into the matter thoroughly in advance.

Guignard is a member of the Academy and is known best for his work on nuclear division, embryology of the leguminosae, and double fecundation. His recent researches are being done on the localization of the active principles in plants.

The library of the School of Pharmacy is very well organized and is especially complete in chemistry. The student will also find, however, that the better known American botanical publications such as *Botanical Abstracts, Botanical Gazette,* etc., can be more easily found and consulted in this library than at the main library. The herbarium is particularly rich in the phanerogams of France. There are about 100,000 sheets, comprising 75,000 species.

Professor Rades is in charge of the laboratory of cryptogamic botany, but this term is rather a misnomer since the work is largely medical bacteriology. His principal research has been done on the mycoses. His laboratory contains one assistant, and this past year there was one student working for the degree of doctor of pharmacy.

The library contains about a thousand titles on cryptogamic botany and bacteriology. The herbarium is not of much value, but a fairly good collection of pathogenic strains of bacteria is kept running. An American in Paris, however, had better spend his time at the Pasteur Institute if he is working in this field. At the institute he will find much better equipment and more congenial surroundings.

The College of Science

Among the botanists at the University of Paris probably the best known, although undeservedly so, is Bonnier, professor of general botany. While he has published various papers on respiration, assimilation and experimental morphology, and although he is a member of the Academy and editor of the *Révue Générale de Botanique*, it is very difficult after seeing the way in which his laboratory is at present conducted to understand how he has gained the eminent place he has held. True, he was the son-in-law of Van Tieghem, and that in the minds of many French botanists explains much.

Professor Bonnier is also the director of the laboratory at Fontainebleau, which is located out 55 kilometers from Paris in the famous forest of the same name. This laboratory is one of the very few field laboratories of the world devoted exclusively to botanical research. Located, as it is, in the great forest, it is hard to imagine a place where botanical research could be carried on under a more favorable environment. The laboratory is well lighted and well equipped, so that, in spite of the personality of Bonnier,[1] work there is a genuine delight. The director in charge is Dr. DuFour, a mycologist of long experience and a man who knows the fungi of France as well as any man in Europe. Dr. DuFour adds immeasurably to the charm of a sojourn in Fontainebleau, and it is impossible for one to quit this laboratory without feeling a very personal debt for the many kindnesses he is sure to receive at the hands of this amiable gentleman.

During 1920 and 1921 there were 24 research workers at the laboratories in Paris and in Fontainebleau. Four students re-

[1] The death of Bonnier in Dec. 1922 was reported after (*post non propter*) this article was prepared.—O. R.

ceived their doctorates and ten others were engaged on theses which they intended to present for the degree. The remaining ten were stray workers who were at Fontainebleau or Paris in connection with some special private problem. The four theses presented were on the anatomy of the liliaceous flower, the morphology of the Marchantiaceae, researches on the Frankeniaceae and the Euphorbias of Madagascar.

The herbarium of the Sorbonne is largely of French flora. Among the phanerogams there are about 18,000 sheets with 6,500 species. The cryptogams are represented by about 2,000 sheets covering 1,200 species. This is not a large herbarium, but, as mentioned above, all workers have the use of the museum collections. The library is poorly organized.

Dangeard, the well-known cytologist and Academician, is also at the University of Paris. He gives the courses in elementary botany for the pre-medical students and conducts a private laboratory of research near the Jardin des Plantes. Unfortunately his laboratory is not open officially for research students without special arrangement. This is a university regulation and not strictly in accordance with the wishes of Professor Dangeard, who would welcome to his laboratory American students of the proper training and give them all the supervision and advice possible. His laboratory will not hold more than two students because of lack of space and equipment, and it would hence be best to make arrangements in advance. However, if any student is going to France to study cytology he will nowhere find a more cordial welcome than with Dangeard, and if there is any way in which he can be accommodated he will find nobody more willing to help him.

Dangeard's principal researches have been in the fields of protistology, reproduction in the fungi, and in the field of anatomy and cytology. He is director of *Le Botaniste*, now in its fourteenth series. He is assisted by his son, who works in the same laboratory and who has also made several contributions to botanical science.

Aside from Bonnier's laboratory of research at the Sorbonne there is that of Molliard, professor of plant physiology and dean of the Faculty of Science. Molliard's chief researches have been made on the morphogenic action of various organic substances on the higher plants, the production of citric acid by *Aspergillus niger*, and the physiology of plant galls. At the present time he is working on an eight-volume text of plant physiology. Two volumes have already appeared and give promise of a work truly monumental. This is the most complete work on plant physiology which has appeared since the well-known German texts and deserves wider attention than it has thus far received in this country.

In Molliard's laboratory there are six assistants and instructors, two of whom are working on the doctorate, their theses being "The action of acids on the composition of plant ash" and "The effect of acidity on the formation of organic acids in the higher plants."

While this laboratory is better equipped for researches in plant chemistry than for those in plant physics, the worker will find Professor Molliard as generous with funds as conditions permit, and any necessary apparatus can always be secured. For the plant physiologist in Paris there is no laboratory which offers as many attractions as this and none where the researcher from America will be more cordially given a place.

This completes our list of facilities in Paris. And what is the conclusion? Simply this: Go to Paris without anticipating the splendid buildings and the abundance of equipment which characterize many of our American universities. However, for everything you miss you will find somewhere something to take its place, and what one loses in external facilities he gains in increased initiative and independence. And, moreover, no American should study botany too hard when he is in Paris.

THE STUDY OF LIFE AS A THING WORTH DOING

A Suggestion for Undergraduate Students

By ALBERT L. BARROWS
NATIONAL RESEARCH COUNCIL

YEARS ago when I was in college I had a teacher of biology who had become a national authority on bees. He was very fond of them. He had gone on from that earlier achievement to studies of other useful insects and to studies of insect pests of crops. He knew a great deal about them. He spent much of his time going about the state showing farmers and orchardists that a thorough knowledge of these things could be of great importance to them—that is, that biology was of practical value in agriculture. But what he labored to show his students in addition to this was the wonderful way in which this strange thing which we call life works. He tried to paint a picture of this life force in the structure and physiology of an individual animal or plant and the way in which this force has passed itself on from age to age through countless kinds of animals and plants. How this came about was to him the all-absorbing problem. This same problem is one of the questions which men have pondered over ever since the earliest peoples first conceived their ancient beliefs of whence we have come and whither we are going and pictured their ideas on skins and bones or carved them upon the rocks.

Dr. Raymond Pearl has recently described this problem by asking some simple questions: How many kinds of animals and plants are there? How did there come to be so many kinds? And why is it possible for living things to be here on the earth, any way? What is it which makes a living thing so much more wonderful than a rock or the air or a rain-drop? Every one at some time has asked himself these questions in one form or another. Why are we here? Why do we do as we do? Why are all the other animals and the plants here? What are the conditions which make possible this curious phenomenon which we call life, partly chemical, partly physical, partly something else—perhaps? How long did the world have to wait after it was cast off from the sun and while it was cooling down before this puzzling activity of life could be developed, an activity in which certain combinations of the elements

organize themselves into little chemical engines which we call cells and which react to changes in their surroundings, take in food material and grow and finally reproduce other cells and organisms just like or nearly like themselves? This is what living things do and what makes them different from inanimate things. And we should all like to know how it comes about.

This old professor of mine taught us first how to recognize some of the kinds of animals and plants of our region, and how to see exactly those differences which count in making them different. He gave us one day a book to read about the "Origin of Species," the significance of which I am frank to say none of us came near grasping until many years later. But we did gain from this book some idea of the agelong process of development of the varied forms of life, of certain relationships between them and a suggestion as to how it all might have happened. We got the idea, too, that animals and plants have not always been the same, that life is constantly changing, and we gained some conception of the principle of progressive change which we call evolution.

Later I learned something of the wonderful work of Pasteur, who was finally able to show—and not so very many years ago, either—that, at least as things are now, all living beings come from previous living beings, and that there seems no longer to be any such process as the spontaneous generation of life, that conditions must have changed since life first began, that life has gotten its start and is now on its way—on its way toward what?

Life was a very wonderful problem to this teacher of mine, one which seemed to him to be at the bottom of many other problems which we should like to solve in regard to the uses which can be made of animals and plants about us, in connection with the troubles which some of them—the smallest of them—cause us, and finally in the explanation of the histories of peoples and their customs and our own social relationships and activities to-day. He made us feel that one of the most important things a college graduate can do is to study these questions and perhaps make some contribution toward their solution, and add to human welfare thereby, or help to gain a better perspective of the place of man in this universe, so important a place to us, so insignificant to the sun, the moon and the stars.

Some years later other teachers made me acquainted with the clue which Gregor Mendel hit upon, scarcely realizing it himself, as to another possible cause for the course of development of living things, through the operation of the laws of heredity. The present generation of biologists is following up this clue and is trying to find out just how the differences from the average stock are handed

on from one generation to the next. What changes are handed on and what are not? What are the rules under which these changes are combined and re-combined in one generation after another with a variety limited only by ability to get along with the surroundings? How much does habit or the environment have to do any way in stimulating these changes? How much is due to new combinations of characters or interbreeding? How can man take advantage of all this in improving this stock of domesticated animals and plants?

I had also a teacher who, from studying the animals of long ago, had made himself their historian. He told me parts of the wonderful story of animals and plants in the rocks, the successive strata of which are as truly as anything can be the leaves of a great book, showing, if one has but the patience to decipher the record, the changes from one animal or plant form to another and the changes of groups of animals and plants from place to place and from time to time, beginning with the oldest rocks formed by the wearing down of the first hardened earth surface by the washings of the earliest rains into the original seas. This paleontologic record or history of animals gave another clue as to how the scale of life has grown and as to its enormous extent.

My later teachers told me something also about the strange conditions of life in the sea, so different a world from that of the land, but touching right at our very shores. They showed me how all these animals and plants of the sea, feeding upon one another, depend finally upon the myriads of minute plant and animal forms which make up what have been called "the meadows of the sea," flaring up as spring and autumn "crops," and providing the basic organic stuff upon which the larger organisms of the sea survive. One can not help regarding this vast assemblage, with the sea itself, almost as another huge pulsating organism. This gave a clue as to the kind of environment in which the life processes of our world may have started—for there must have been a beginning somewhere.

From another of my teachers I got another suggestion for the unravelling of a part of this riddle of life through the study of the Protozoa, the smallest and the most primitive of the organisms in the animal series, some of which seem to be as close to the first animals as any organisms on earth to-day. This group contains those which seem to bridge the gap between the animals and the plants, the one essential difference between these two great modes of life being that animals can live only on stuff which has already been made up by other living things into substances organized to contain the spark of life, while plants can take their food from the raw

elements. Some Protozoa appear to do both. Nothing, except perhaps the bacteria, has ever seemed to me to show the three functions of living matter—sensibility, feeding and reproduction—more graphically than the Protozoa, in which a single cell carries out the whole life story. Hundreds may come within a single field of view at the bottom of a microscope tube, scurrying ever after food, multiplying at an enormous rate. How is it that from these tiny creatures the force of life has built up the complex organisms all around us with larger and much more complicated bodies? What stimulated the development of the organs of special sense, not only those of touch but those for perceiving light, sound and odors and tastes, from a blind groping among the simplest animals to keen and highly perfected organs which the birds, the forest wolves and cats and we ourselves enjoy? How much development was necessary before animals could become conscious of themselves? What makes the human animals at the latest end of the series concern themselves over their relations to each other, establish laws and form nations, seize the raw materials of the earth and fashion them for their own uses, and begin to reflect upon the principles according to which this has all come about and what it is all leading toward? Is this long chain of related organisms existing only to perpetuate itself in more and more intricate forms, like some other organizations that we know of, created by their founders largely to give the members something to do in running them? It is a long, long story, and the man must have zoological training who would make any contribution to a real solution.

All these questions are, after all, only different ways of putting the fundamental inquiries of how there come to be so many different kinds of animals and plants and what makes them "go." What is this principle of progressive change which we call evolution, a relating of present forms of life to previously existing forms perhaps now extinct, a connecting of current events to those of the past? The astronomer revels in ideas about it, the chemist and the physicist see it in the behavior of the atoms of the elements, the geologist has it always before him in the constant working over and over of the materials of the earth's surface, the historian is the recorder of it in human affairs. But, universal as this principle is, there is no other material than the succession of animals and plants in which the principles of evolution are better and more readily illustrated, though the evolution of life is only one phase of this all-pervading process. It is the special privilege of the biologist to unfold its mysteries as applied to living things.

The biologist goes about answering these questions in many ways and a little part at a time. The man who counts and de-

scribes the different kinds of animals and plants makes perhaps the first contribution. The man makes his contribution also who observes their minute differences or variations, and who studies the results of sorting and cross-breeding. The man who studies animals out-of-doors, their habits, behavior and the ways in which the climate, hot or cold, wet or dry, and the surroundings of plain or forest seem to have affected them, makes his contribution. The microscopist who works out the complexities of the chromosomes of the sex cells adds his part.

And the man who thinks that he is engaged wholly in the practical side of zoology has always at his hand material for the study of these deeper, most fundamental questions. The physician and surgeon are the appliers of highly refined zoological attainments, whether in the history of protozoan and vermian parasites, the theories of epidemics, the development of serums and the underlying theories of susceptibility and immunology, the problems of cancer, the running down and control of the causes of one disease after another, and the conception of the human body as a complete but delicately balanced mechanism furnishing to a certain extent its own protection against disease and its own stimulants and correctives. The progress of medicine is fundamentally a biological matter, whether the subject of study be the human body itself and the functioning of its parts or the organisms which may infest and destroy it. The man who takes up research in medicine has before him one of the largest of the opportunities for service and for strengthening man's control of this world.

Every farmer, too, is a biologist of a sort and there is a greater and greater demand for more complete knowledge of farm animals and plants to be applied to his uses. The farmer wants his breeds of animals improved and stabilized. He wants them protected from disease. He wants the state entomologist to pit his ingenuity against the vital impetus for reproduction in the enormous numbers of insects which are ready to destroy his crops or wants him to take advantage of other insects which can be made useful in a war upon their own kind. He wants to know why differences in soils affect his crops and what are likely to be the long time results from fertilization and from irrigation in producing better crops, together with the liability that new insect hordes may attack them under these artificial conditions.

It is only comparatively recently that we have realized that the wild animals which we have preyed upon for food and leather and furs must be protected against extinction, and that these natural resources can be actually increased by wise control based upon a sound knowledge of the biology of these animals. The conserva-

tion of game for the recreation of hunting and fishing, the preservation of the fur seal herds and of the salmon, cod, herring and oyster fisheries are all problems for the practical zoologist. We can offer ourselves no excuse if we do not take the means which investigation is sure to show to keep these great natural resources productive. These are some of the questions now open for zoological research.

There are many opportunities for engaging in such investigations as these, whether in connection with teaching or in connection with the application of zoology to medicine, agriculture, fisheries or other industries. But a research position is no place for the man who wants merely to make money nor for the man who, despite his college education, is likely to find difficulty in holding his own in any profession. Research work calls to the most able students, those who have sufficient natural ability to be sure of a living in whatever they undertake and who can devote their main interests to the larger purposes of their work. Zoological, or one might better say, perhaps, biological research, appeals to those whose fundamental interest is really in the problem of life. Into this work must be combined the experience of the chemist and the physicist, the lore of the geologist, and the training of the mathematician and something more—the observations peculiar to the special study of living things.

Above all, a research career calls to men who crave to know the unknown. It demands a spirit of adventure, a willingness to pioneer upon the frontier of present knowledge, an imagination to be able to guess, and guess correctly, the meaning of what is learned, and an ability to lead in thought out beyond that which is already understood, to wrest from the beyond new facts and new ideas, to deal with uncertainties, probabilities and sources of error, until one can find a treasure of fact which will make the uncertain sure and the incomplete more nearly complete.

Zoological research has not only contributed in important ways to our physical well-being and prosperity, but in contributing to our knowledge of why any living beings are here, the life sciences lay the basis for attacking the eternal problem of why in the endlessly rolling processes of this enormous inanimate universe there should occur a brief stage under certain nicely balanced conditions when a few select materials may organize themselves into a succession of beings which eventually become aware of their surroundings and then of themselves, and in their highest examples finally acquire a considerable power for self-direction and manipulation of the materials around them.

No zoologist ought to enter upon his researches without at least an occasional thought to this ultimate question. And no student should allow himself to be drawn into this impelling course of life-long study who has not analyzed himself to make sure that he has the requisite qualifications, nor unless he is unable to resist a consuming desire to know more of the riddle of life, at once the most interesting and perhaps the most baffling of the problems on which we can now engage. But there is a solid satisfaction in store for the zoological investigator in the successful development of his students, if he is a teacher, and in the contributions which he can make to knowledge in the application of this knowledge to human welfare, and in the consciousness that he is engaged upon a study of the fundamental problem of life and of the development of the life process to the human stage in which we can undertake an examination of this life and of its position in the general scheme of things.

A FISHER OF MEN AND MINNOWS

By Professor T. D. A. COCKERELL
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In one sense, we doubtless exaggerate the importance of our "great men." Once a man becomes a national figure it is possible to write or converse about him without having to explain who he is. Let him utter platitudes, and they are quoted as gems of wisdom, partly because they confirm from a high source the commonplace ideas of the multitude. Those who publish their recollections are proud to recall every contact with persons sufficiently famous or infamous, but have little to say about those who may have meant more to them, but remained unknown to the great public. Indeed, to have a "name" is a commercial asset, and in these modern days we have the spectacle of numerous persons conspiring to confer distinction on the incompetent and vicious. The public is perhaps only partially deceived, but it has no sufficient standards of its own, and is willing to give its attention to anything which is forced upon it. Even street songs acquire tremendous vogue almost regardless of their meaning or literary values. Mimicry is, after all, the cheapest form of expression.

Reflecting on these things, it is possible to grow pessimistic, and thereby to overlook the very springs of human progress. New movements and new ideas originate with individuals, and the intellectual work of the world is carried on comparatively few shoulders. Put aside entirely the question of "distinction," and ask how many, exactly, are carrying forward a certain line of endeavor. The answer will astonish those who have not considered the matter. There are numerous really important branches of science to which contributions are being made in the whole of America by less than a dozen persons. In a population of a hundred millions the productive scientific group numbers only a few thousands, yet its work affects us all every day of our lives. Regarding things in this manner, we are dealing with objective facts, and no question can remain concerning their validity.

In the fields of education and public policy, our judgments can not be so definite, if only because the work is far less individual. The very fact of social leadership implies a certain lack of originality, a disposition to join with others for a common end. Yet in the

midst of the confusing cross-currents of human affairs, the man who can orient the forces of society to produce a purposeful flow is a benefactor of a very high type. History will truly record that for certain important purposes he was indispensable. With the passage of time and in the light of subsequent events, it is possible to distinguish between functional significance and mere notoriety.

The newly published autobiography of David Starr Jordan[1] records seventy years of the life of one who showed an extraordinary capacity for work and leadership in the fields of science, education and public affairs. It will be read by many who have known Dr. Jordan, or have had some part in the movements in which he was the leading figure. Vernon Kellogg, writing in *Science*, has well expressed the attitude of such readers, to whom the subject is too near and dear to permit of cold analysis. A larger public, and particularly those of later generations, will find in the story an illustration of the higher possibilities of American civilization, worthy to be studied by those who wish to see a better world. The scientific student, interested in social phenomena, will try to distinguish the effects of heredity and environment, asking exactly what we mean when we describe Dr. Jordan as a characteristically American product.

Since our subject is unique amongst so many millions, it is easy to affirm that inborn capacity sufficiently explains the phenomenon. Yet this capacity developed along the lines of opportunity, and no one can study the life without perceiving that the total result depended upon a vast number of circumstances, trivial or otherwise. Certainly no human being has ever attained his maximum potential efficiency, because a perfectly suitable environment has never existed. Simpler organisms may sometimes do this, but our life is so complex and so full of chances for error and failure that we must marvel at even moderate success. Unless society can be organized on a better basis, the proportion of failures, partial or complete, may increase until life is hardly worth living for the majority. It is this evil consummation that we must prevent by using whatever wit and good will we may possess. The contemplation of Dr. Jordan's life, representing a very high degree of success in utilizing the gifts of heredity, should at least give us useful hints, aiding our efforts to promote like results in the future.

We get the impression of the wholesomeness of American rural life in the fifties and sixties of the last century. It combined a certain simplicity with reasonable educational facilities; free from the feverish excitements of metropolitan life, and yet lifted far

[1] "The Days of a Man" (two volumes), World Book Company, Yonkers-on-Hudson, N. Y., 1922.

above the trough of dull-witted ignorance in which the country population of England was largely submerged. Good books were available and the idealism of the period reached many out-of-the-way places. The older folks had, in general, struggled successfully with the forces of nature, and knew where real wealth came from. Without pretending that conditions were ideal, we may recognize that there were elements of greatness diffused through the social organism, ready to come to a focus when meeting with capacity. No rigid political or economic doctrine can adequately explain such a situation; it is almost as subtle as personality, and similarly potent.

In his eighth or ninth year, Jordan had a wonderful trip with his parents. Taking a horse and buggy, with a little stool for the boy, they drove fifty miles to Irondequoit, near Rochester, on Lake Ontario. They then went 25 miles to Albion in Orleans county, every mile of the way full of new wonders for the child. "That trip to Rochester stands out in my memory as a sudden disclosure of the great world which I have ever since tried to explore and understand." But, adds Dr. Jordan, an automobile would now cover the entire round trip in five hours. Cover it, no doubt, but the old-time horse and buggy uncovered it, in all its glorious details, to the astonished gaze of the future naturalist.

Home influences were wholly salutary. Jordan's parents left the Baptist church because they could not accept the then prevalent doctrine of "infant damnation." The boy was surrounded by "strong religious influences untouched by conventional orthodoxy." The parents had "the Puritan conscience, and were very rigid as to personal conduct, deprecating all forms of idleness and dissipation generally." Tobacco and alcohol were not used, and cards were regarded as a waste of valuable time. A minister, Mr. J. L. Jenkins, took young Jordan on geological excursions, and awakened a strong interest "in the make-up of the earth." He urged the parents to send him to college, though at first there was some hesitation. In 1869 Cornell University, recently founded, offered free scholarships, and in the competition for one of these, Jordan was successful. He accordingly went to Ithaca, with only 75 dollars in his pocket, "but rich in hope and ambitions."

At Cornell he earned his living in a variety of ways, and boarded at a club known as "The Struggle for Existence," generally abbreviated to "The Strug." While still an undergraduate, he was made instructor in botany. Several of his college friends were interested in various phases of natural history, and have since become well known from their work. Thus Jordan rapidly developed into a trained naturalist, but the beginnings both of his in-

terest and of the moral stability which led to success long antedated entrance to college. Cornell, however, was an inspiring place, and after the lapse of years, he has this to say about it:

> The early days of my Alma Mater, though relatively crude and cramped, were enriched by an enthusiasm hard to maintain in days of prosperity. And the pioneer impulse far outweighed, to our minds, any deficiency in coordination, equipment or tradition. At that time we were all young together, freshman students, freshman professors, freshman presidents without experience or tradition to guide or impede. But we had youth and we had truth, and not even the gods have those!

After graduation came opportunities for teaching, and the beginning of leadership in scientific activities. Evidently Jordan would have been a leader of men under almost any circumstances, but it is no small matter that he chose the lines he did, and this must be ascribed mainly to the influences and opportunities which came to him. Furthermore, the relative freedom of American educational institutions gave him his chance, and all things considered he met with far more support than opposition in developing genuinely liberal and scientific culture. The summer with Agassiz at Penikese made an indelible impression, and is thus epitomized:

> So the summer went on through a succession of joyous mornings, beautiful days and calm nights, with the master always present, always ready to help and encourage, and the contagious enthusiasm which surrounded him like an atmosphere never lacking. A born optimist, his strength lay largely in a realization of the value of the present moment. He was a living illustration of Thoreau's aphorism that "there is no hope for you unless the bit of sod under your feet is the sweetest in this world—in any world."

This, we remember, at the very end of Agassiz's life, spent in high endeavor. Jordan expected to be a botanist, but took up fishes because they seemed to offer better opportunities for research. It is probable that he had a special, inborn capacity for biology, but certain that he might as well have been a botanist, ornithologist, entomologist or conchologist as ichthyologist. Agassiz's influence was probably a deciding factor, and we can say now that no better line of work could have been chosen. The magnitude of Jordan's ichthyological labors (by no means finished) can not be readily estimated with accuracy, but few zoologists have covered more ground or made more discoveries. A mere catalogue of the new facts brought to light would not suffice, as it would leave out of account the gigantic labors of setting in order the fish faunas of North America, of the Hawaiian Islands and Japan. The details of the work may be criticized, and posterity will propose changes in the system, but the truly pioneer work has been done once for all. Very recently, Dr. Jordan has published

a bibliographical work covering all known generic names of recent and fossil fishes, which will be an indispensable handbook for all future workers.

On the first of January, 1885, Jordan became president of Indiana University, which at that time had only 135 students of collegiate rank. He had not wished to assume executive duties, expecting to devote his life entirely to natural history and exploration. He was thus chosen, against his will, because his capacity for leadership and clear ideals for education had already become abundantly manifest. It is greatly to the credit of the trustees, and the people of Indiana in general, that they were anxious and willing to take a man with a thoroughly modern outlook, who knew what he wanted and would not be driven by the winds of transient opinion or led by the lure of political opportunity. Dr. Evermann, referring to Jordan's work in Indiana, said (1916) "the influence upon the state was epoch-making."

Of Jordan's methods in Indiana it may suffice to say that they were inspired by democratic ideals, without being subservient to public opinion. He sought successfully to create an enlightened public opinion by going everywhere, making speeches and getting in touch with leaders in local and state affairs. Later, in California, he did the same thing. Political methods, if you like, but methods which ultimately affected the thought of great masses of people and made it possible to give every competent young person a chance for higher education. With all this, he did not abandon research on fishes, and one wonders how he found enough hours in the day to do his work.

When Mr. and Mrs. Stanford planned to found a university in memory of their son, they sought out Jordan of Indiana as the man who seemed most competent to carry out their wishes. Their point of view had been strongly influenced by Agassiz, for whom they had a respect almost amounting to veneration. Thus it happened that once again liberal and progressive opinions triumphed, and the door of opportunity stood open. What came of it all is a matter of recent history.

Assuming, as we may assume, that people with capacities similar to Jordan's are not unfrequently born in this wide land, how can they be fully utilized? Are conditions now as favorable as they were during Jordan's period of development? Superficially they appear to be more favorable, at least in a number of respects. Whereas the struggle for adequate opportunity was formerly severe, we now thrust advantages before the student. Fine laboratories, great libraries, all are his to use to the utmost. Agricultural colleges provide for the sons and daughters of farmers; normal

schools are everywhere training teachers according to approved methods. In the natural sciences, the work is much better organized than ever before. Most groups of animals and plants have been intensively studied, and splendid monographs abound. Museums, filled with priceless treasures, have developed in various parts of the country. Are we not in all respects most fortunate?

Yet, in spite of all these advantages, things are somehow wrong. A recent visitor from England remarked on the fact that scientific men appear to have less prestige in America than in Britain. The sort of life and the ideals which irresistibly attracted young Jordan are perhaps losing their charm. Agassiz could not do now, were he with us, what he did fifty years and more ago. In spite of our schools and colleges, and the growing number of university graduates, scientific research is poorly supported, and even when accomplished can only be published with great difficulty. Much of the literature sent out to arouse interest in the great schools (not excepting Stanford) gives one the impression that they are sporting clubs first and educational institutions second. When the alumni get together, it is usually to talk about athletics, or to witness a game. The people seek continual amusement, as though the personal activities of real life had lost their meaning. The degradation of the arts has gone to a point which could hardly have been imagined fifty years ago. The stupidities of the Victorian era were rather due to special conventions or limitations than to the abandonment of all desire for accuracy or beauty. The developing world-civilization, which we thought would make wars impossible, actually produced the most terrible and barbarous conflict yet known.

Must we then say, as we put down Jordan's book, It never can happen again? If we are resolved not to believe that, it is necessary to get a changed point of view. The president of Antioch College, in my hearing, recently said two things which have lingered in my mind. Asked whether he considered the arrangements at Antioch final, he said, "No, it is an experiment, and I hope it will always be conducted in that spirit." Asked whether Antioch was, like other schools, unduly dominated by competitive athletics, he said, "No, because real work compels amusements to take their proper place." The spirit of scientific work is experiment guided by experience, and thus it stands ever on the fringe of knowledge inspired by hope and expectation. The educational process should have a similar motive, for the morrow of every day promises something beyond. Defects in our economic and political systems, bad as they may be, do not account for the modern state of mind, nor are our young people intrinsically inferior to those of other days.

It has been justly remarked that the sources of modern degradation are, broadly speaking, not with the young at all, but due to the dominance of an actual minority of middle-aged or elderly people.[2] The young, on the whole, mean well enough, but are as sheep without a shepherd. Jordan thought Cornell, in the early days, owed its virtue to the spirit of youth. Again at Indiana, rapidly developing from small beginnings, was the bright spirit of adventure, free from pessimism or cynicism. So again at Stanford; say what you will, Stanford to-day is not what it was. The young, given a fair chance, will respond to ideals of virtue and beauty, but they will not create them unaided. They will not maintain them without adequate leadership. Leadership implies social sanction, which itself was developed originally through the efforts of individuals. Actually, we are moving forward, and many encouraging tendencies may be observed, but we need to find our Jordans and then give them a chance to act.

[2] If any one doubts the possibility of this, let him consider how fashions in dress are controlled by a small minority for commercial purposes and imposed with ease upon a pliant and mimetic public. They are not necessarily bad; occasionally they are beautiful, but sensible or absurd, beautiful or ugly, the success of the propaganda is the same. On the other hand, the pictorial side of commercial advertising, which depends for its success on genuine realism, can not afford to do without artistic skill, and often maintains a remarkably high level of excellence. The degeneration of art and literature comes about when sincerity of purpose has departed.

STANDARDS OF LIVING AS THEY AFFECT THE GROWTH OF COMPETING POPULATION GROUPS

By Dr. WARREN S. THOMPSON
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In the growth of population in competing groups, under present conditions, there seems to be a law at work somewhat analogous to Gresham's law regarding the effects of competition between different types of money. It may be stated thus: *When groups of people (races, nationalities, classes) having different standards of living come into competition that group having the lower standards tends to displace and supplant the group or groups having higher standards.* The phrase "come into competition" is used here to signify any situation in which groups find themselves pitted against each other in their daily efforts to make a living.

The proof that groups with lower standards of living displace and supplant those having higher standards is to be found by studying population growth in those parts of the world where competition between such groups is going on.

The Competition between Nationalities

Probably no portion of the world offers clearer illustration of these processes than the eastern and southeastern fringe of Central Europe. Of this region an eminent authority says:

> Another striking fact . . . is that the lower cultural groups are, at least temporarily, pushing back those of the higher cultural levels. The Pole of Posen is pushing back the Prussian, the Ruthenian is pushing back the Pole in Galicia, the Lithuanian is beginning to make headway against the Pole also at another point, and the Italian in Austria is pushing back the German. Naturally the isolated individual tends to be absorbed by the larger groups, and the question of the expansion of the populations of the lower cultural levels is largely a matter of the birth-rate and of the standard of living. . . .

In Posen the Poles have long had a higher birth-rate and a larger natural increase than the Prussians. In the decade 1871–80 the birth-rate in Posen was 46.2, while in Prussia (including Posen) it was 40.7. The rates of natural increase at this time were 16.2 and 12.5, respectively. In 1913 the birth-rate in Posen was 34.4, in Prussia 29.1 and the rates of natural increase were 17.1 and 13.3, respectively. Thus we see that the rates of natural increase in Posen are considerably higher than in Prussia. Because of this the

Poles steadily pushed westward into German territory and the German statesmen were alarmed at the supplanting of the Germans by the Poles. Bismarck, who was the author of the policy of forcible Germanization, said he was not afraid of the Polish man, but of the Polish woman because she was so prolific. He is credited with saying that the Poles multiplied like rabbits, while the Germans only multiplied like hares.

We are not here specially concerned with the social effects of the policy of forcible Germanization of the Poles, but it is interesting to note that in so far as it placed the Poles under economic and cultural disabilities and thus kept their standards of living low it defeated its own aim by keeping the birth-rate and the rate of natural increase high. Because of this rapid increase of the Poles the spread of German culture was checked and the tendency was for the Germans in Posen to be Polonized rather than for the Poles to be Germanized.

The same process has been going on in Hungary, where Slovaks, Roumanians and other nationalities are in contact with the Magyars. Mr. Seton-Watson sums up the situation as follows:

> In the thirty years preceding the last census (1870–1900) the Magyars have gained 261 communes, but lost no fewer than 456 (a net loss of 195): while the Roumanians, though they lost 42 communes to the Magyars and 22 to other races, have gained 362 communes (a net gain of 298). The Slovaks have gained 56 communes from the Magyars, but lost to them 89 others; but they have made good this loss by a net gain of 175 communes at the expense of the Ruthenes. Meanwhile, the genuine Magyar population is beginning to lose ground; emigration has thinned its ranks, and in recent years the "two-child system" has made alarming strides, especially among the peasantry of Baranya and Vos.

That this process of displacement of the Magyars by nationalities of lower culture is going on receives confirmation from a comparison of the vital statistics of Hungary and Roumania. The natural increase of Hungary for a number of years before the war held at about 11.0, while in Roumania it varied from 13.0 to 17.5, generally being 14.0 or 15.0.

There is little doubt that much of the chauvinism of the Hungarians, manifested in their attitudes toward their subject nationalities, grew out of their very real fear of being supplanted by the more prolific stocks by whom they were surrounded. As in the case of Prussia, the repressive measures taken to bring about Magyarization only served to arouse the nationalistic spirit in the subject groups and to keep the birth-rate high by placing them under certain economic and cultural disabilities.

There is no need to multiply examples of localities in which the struggle of nationalities for expansion is being decided by the abil-

ity of one nationality to live more cheaply than its neighbor. It is a process whose existence is generally recognized by those who have given some little study to the conflict of nationalities in modern Europe.

The Competition between Races

In the United States the white and negro races have never really "come into competition" within the meaning of that phrase as defined above. They have lived in different spheres of life. Consequently, the much more rapid rate of increase of the whites (16 per cent., of which about three fourths is natural increase, as against 6.5 per cent.) is not to be regarded as disproof of the general thesis stated at the beginning of this article, but rather as the failure of a "primitive" race to make satisfactory adjustments to the civilization of a more developed race. In the case of the Japanese in California, where there is no question of a "primitive" race involved, we have the beginning of a real competition. Of the native white women in California 20 to 49 years of age only 6.7 per cent. reported births during the year 1920, while 27.1 per cent. of the colored women other than negroes of the same age group reported births. A considerable proportion of these "other colored" are Japanese. When all due allowance is made for the tendency of many Californians to exaggerate and misinterpret the facts, we must still conclude that the rate of increase of the Japanese is much greater than that of the whites. The effects of this are seen in their efforts aiming at the expansion of the colonies already established and their desire to acquire lands to establish new settlements.

It is the feeling that white men have little or no chance to survive in competition with the Japanese that lies at the basis of the agitation against their immigration into Australia and Canada and into our own western states. Of course, what is called "race prejudice" enters into the account, but "race prejudice," in large measure, consists in antagonism aroused by differences in the modes of living of different groups.

The fact that the Japanese have excluded the Chinese and Koreans (the latter the inhabitants of one of their colonies) from certain occupations in Japan shows that they have this same feeling with regard to immigrants who are willing to work harder and live on less than they themselves are.

An experienced observer of the far east, Mr. J. O. P. Bland, frequently mentions the inability of other races, but particularly the white race, to compete with the Chinese. Along the Manchurian railway the Russian is not holding his own against the Chinese. He is soon found in the lower economic positions and he

must retreat or die out because he can not live as cheaply as the Chinese coolie with whom he has to compete. The Chinese can not be excluded from this area as we are able to exclude them from America because the frontier is a land frontier.

The Competition between Classes

When classes of people of the same nation come into competition, the classes with the lower standards of living supplant the classes with the higher standards in the same way that nationalities and races with lower standards of living supplant those having higher standards. About 25 years ago (1897) J. Bertillon presented data showing that in the largest cities of Europe there was a progressive decrease in number of the children born annually per 1000 women aged 15 to 50 as one proceeded from the slums to the quarters of the rich. He gives this decrease as follows: In Paris, from 108 in the very poor quarters to 34 in the very rich; in Berlin, from 157 to 47; in Vienna, from 200 to 71; in London, from 147 to 63. It has been found that in London (1903) the *corrected birth-rate* (that of the whole of London being taken as 100) was 118.8 in the poorer quarters, about 95 in the middle class quarter and 77 in the quarters of the rich. Dean Inge, in a note to his essay on the birth-rate, says: "The births per 1000 married men under fifty-five in the different classes are: Upper and middle class, 119; intermediate, 132; skilled workmen, 153; intermediate (workmen), 158; unskilled workmen, 213."

In our own country there is abundant proof that the people with higher standards of living are being displaced and supplanted by those with lower standards. People of native stock in the cities and in the northern and western states are fast being supplanted by immigrants and their children. Graduates of women's colleges have scarcely enough children to replace themselves, to say nothing of replacing their husbands. Small cities in the eastern states having distinctly different population groups—*e.g.*, Auburn, Maine, largely of native stock, and Lewiston, Maine, largely of French-Canadian stock—have large differences in their birth-rates, that of the latter being about 10 per 1000 higher than that of the former. The studies of the Immigration Commission showed that in several different localities the number of children born to mothers of foreign parentage averaged much higher than the number born to native-born mothers of native parentage and that the difference was greater in cities than in the country.

Recently the Census Bureau in its report on birth statistics for 1920 has set forth a number of interesting facts in the tables relating to the size of families. In North Carolina during 1920 14.9 per cent. of the native-born white women 20 to 49 years of age reported

births, in Ohio the percentage was only 8.4, in New York it was 7.6, in Kansas 9.9, in Washington 8.2, in Virginia 12.5. Thus it appears clear that in the south, where the standard of living is lower than in the north, children are more numerous. This is also shown by the number of children born to the wives of men engaged in various occupations who reported births during 1920. The wives of professional men had born about 2.2 children, the wives of miners had born about 4.3, of farmers 3.8, of bankers, brokers and money lenders 2.3, of managers, superintendents, etc., in manufacturing 2.5, of laborers in manufacturing 3.7 and of semi-skilled operatives in manufacturing 3.0. So far as one can judge of economic status from occupation there is no question but that the better this is, the smaller is the number of children born in the family.

The evidence that this process of the supplanting of people having higher standards by those of lower standards is going on all over the world is conclusive. A higher standard of living has no biological value. It tends to substitute voluntary control of population growth for the processes of natural selection. It seems quite probable, therefore, that if people having high standards of living expect to survive they must be prepared to control the processes of competition between themselves and people with lower standards, both by restricting the movements of peoples and by encouraging the spread of knowledge regarding the means of birth control to all classes of the population. They must also learn to use birth control as a method of limitation rather than of elimination as is so often the case at the present time.

The Causes of the Supplanting Process

Greater Economic Efficiency and its Consequences

The reasons for the supplanting of people with higher standards of living by those with lower standards when the two come into competition are not far to seek. The people with lower standards generally share in the benefits of a more efficient economic system developed by the people of higher standards so that they obtain a larger return for their work than they are accustomed to. They work with the capital accumulated by people with higher standards or they sell their produce in a market developed by a highly organized transportation system or they make use of the labor of women and children in productive processes in a degree not customary among people with higher standards. Though most of the increase in product obtained by more efficient work goes to the employing class, sufficient goes to the laborer to give him command over more goods than he had under the less efficient system. This surplus acts immediately to remove some of the economic causes of a high death-

rate. Thus a larger number of the children born to these people survive and their rate of natural increase mounts rapidly. Parents can feed, clothe and house more children than they could have done with the same expenditure of energy under a less efficient system and yet have more for themselves than ever before (more leisure, better clothes, better food, better house, more furniture, etc.). Thus it happens that the rearing of the larger proportion of children that survive because of the easier struggle for existence is not felt as a hardship.

Improved Sanitation

When coming into competition with people having higher standards, people with lower standards also share the sanitary improvements of the latter. The advantages of a good water supply, closed sanitary sewers, medical clinics, school medical examinations, etc., where they are present at all, are rapidly extended to the lowest economic classes. If no higher motive prevails, self-protection serves to stimulate the extension of health agencies to all classes. The result is that the people with lower standards who always have a higher birth-rate increase more rapidly than those having higher standards. This condition lasts for some time, often for generations, for the forces working for a reduction of the birth-rate are much more complicated than those working to reduce the death-rate and do not come into operation so quickly.

The death-rate depends directly upon the economic status of a group. So direct is the relation between the economic condition and the death-rate that if one were to arrange the countries of the world in order of their death-rates, one would find that, almost without exception, they were also arranged in order of the economic welfare of the masses of the people—the highest death-rate existing where poverty is most pronounced. This is just as true of the different economic classes within a country as it is of different countries. The only exception that needs to be made to this statement is that if the age and sex groupings in a country or class are peculiar the death-rate of the groups so affected will reflect this peculiarity, so that on the face of the figures the above statement may not appear true, while a corrected rate will show its truth beyond dispute.

The Causes of a Lower Birth-Rate

An enumeration of the forces making for a reduction in the birth-rate will show that these forces are much more complicated than those making for a reduced death-rate and are much more closely associated with the whole cultural development of people than the latter. As a consequence the birth-rate does not respond

to a change in economic conditions in the immediate way in which the death-rate does. The forces making for a reduction in the birth-rate may be summed up under the following heads: ambition, desire for self-development, love of luxury and ease, desire to give one's children the best possible start in life and sterility due to vice and also probably to over-eating and sedentary life. These are the "preventive" checks. It will be seen that all but the last of these, *viz.*, sterility, may be called "psychological." That is, they come into operation because of the desire of people to limit the size of their families. Whether people will have this desire and how strongly it will operate will depend upon many factors—the nature of one's ambition, the accustomed standard of living and the ease or difficulty of maintaining it, the education desired for one's children, the relative values one places upon material and spiritual achievement and many other factors which cannot be enumerated, but which may be summed up in the expression, *cultural atmosphere*. Since the whole body of habits, traditions, customs and interests which go to make up the cultural atmosphere change much more slowly than the economic conditions, especially in the case of immigrants and of the nations which are coming within the sweep of modern industrial development, the birth-rate of these people changes more slowly than their death-rate. The result is a great and almost immediate increase in the rate of natural increase of people having low standards of living when they come into competition with people having high standards.

The "psychological" causes of the reduction of the birth-rate just enumerated lead to its voluntary control by individuals through postponement of marriage, through remaining unmarried and through limitations of births after marriage. There will be no serious question in the minds of most people that the upper economic classes are those who will make most use of these means of keeping the birth-rate low. Let the reader who questions this position ask himself: What class of people (men or women) are most ambitious? What people need to provide longest for their children—especially for their education? What people feel the need of travel and leisure to develop themselves and make their contribution to the work of the world? What people find their earning power relatively low from 25 to 40 or 45, just when they should be raising a family? And, finally, what people become lovers of an ease and luxury incompatible with the raising of a fair-sized family?

What can be done about it?

It was said above that a high standard of living is not a biological virtue. If people who possess high standards of living are to perpetuate themselves and maintain good standards two things

would seem necessary: First, they must see to it that their standards of living are not so complicated and elaborate that they make no allowance for the raising of fair-sized families. A high standard of living does not need to be a luxurious standard and love of luxury, ease and desire for self-development must not be over-emphasized. This means that a great many middle class and wealthy people must simplify their mode of life and that the ideal of a satisfactory life which they set up must be made to include the rearing of a fair-sized family. The atmosphere in which they live and the general class standards they uphold must be revised so that they favor a fine type of family life. They must come to regard success in life as involving the raising of a family of three or four children so that they will feel that they have failed of complete success in so far as they do not do this. Standards, ideas, customs and habits which interfere with this should be placed under the ban of class disapproval. I am fully aware of the obstacles to the erection of a fine type of family life into one of the effective ideals determining conduct, but unless this is done the people in the upper classes and those nations which have worked their way to the higher cultured levels will perish from the earth in a few generations. *"Blessed are the meek; for they shall inherit the earth."*

There can be no doubt that the people in the upper classes of all nations belong to that half of the nation which has the better inherited capacities. That it is a calamity to a nation to have its better stock die out as rapidly as it is now doing in most of the nations of the western world will be generally admitted. But not only are the people of proved ability leaving few or no descendants, so that there is a constant dying out of their families, but the cultural achievements of these people are also retarded in their spread because of their lack of offspring.

There is a social inheritance just as there is a biological inheritance and the family is the most efficient agency for the transmission of the former as well as the only recognized agency for the transmission of the latter. It is not too much to say, therefore, that even if there be an inexhaustible supply of first-rate ability among the people of the poorer classes, yet the progress of a nation is greatly retarded by the failure of the upper classes to raise fair-sized families; for the very great advantage of being reared in a family where cultural attainments are considerable is thereby denied to almost all the members of each new generation. Thus each person who aims at cultural achievement has to start at or near the bottom of the ladder and naturally he can not go as far in his lifetime as he could if he had had the advantages of being reared in a home where cultural attainments of a high order were a natural

part of his social inheritance. Thus the failure of the upper classes to propagate themselves is both biologically and socially a calamity.

The second thing that must be done if people having high standards of living are to perpetuate themselves is to prevent a too sordid economic competition between themselves and people having lower standards. We already recognize this fact in numerous ways. We are now restricting immigration and are likely to still further restrict it in the near future. We have had child labor laws for some decades and are constantly strengthening them. Thus we prevent parents from depending upon the economic activities of children to add to the family income, and at the same time prevent competition between adults and children. We have compulsory education laws; we have minimum wage laws; we have laws fixing the conditions under which people may work; we have workmen's compensation and employers' liability laws; we have labor unions fixing the numbers of apprentices, the methods of their choice and the periods of training, also fixing the hours in a day's work and making many other regulations regarding the conditions of work. All these restrictions tend to make it possible for certain groups to maintain standards of living which they would not be able to maintain if competition were unrestricted between themselves and people having lower standards.

I would not hold that it is desirable to maintain all the standards of living we are now maintaining by restricting competition between groups. Too much restriction may lead to stagnation of effort on the part of any group or class; but I would hold that when a group (race, nation or class) has raised itself out of the slough of poverty it cannot be expected to sit calmly by and watch itself perish from the earth because other peoples are still in the slough. For, if competition is unrestricted, the people with lower standards are the ones who will survive. Just as the baser money drives the better money out of circulation because the former is relatively over-valued, so people with lower standards of living supplant those with higher, because their qualities have a greater economic and biological value, that is, are over-valued, in a system where mere volume of production is made the test of national greatness and acquiring the ownership of large quantities of the products is the chief test of the individual's success.

SOURCES OF WATER SUPPLY FOR DESERT ANIMALS

By VERNON BAILEY

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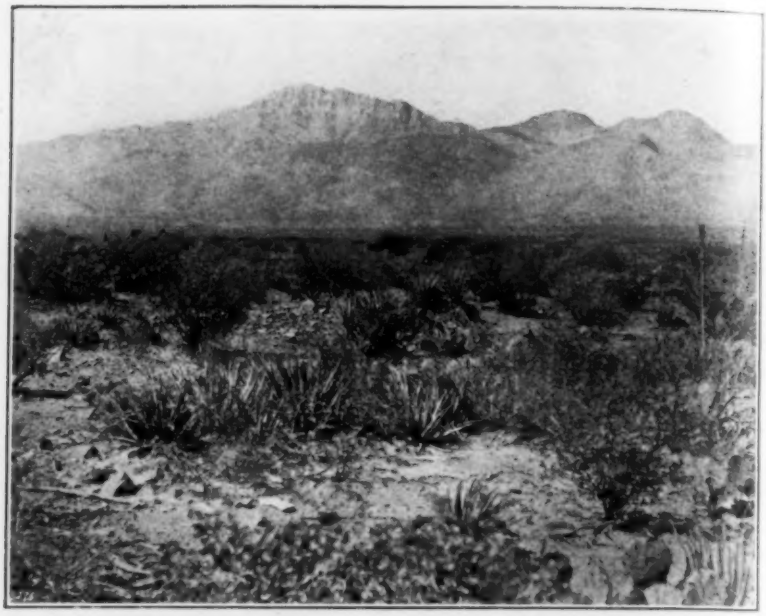
THE well-known fact that our driest deserts are abundantly populated with animal life has caused much surprise and speculation. Insects, reptiles, birds and mammals are generally common and, in varying proportions, often far more numerous than in humid climates of flowing streams and dense vegetation.

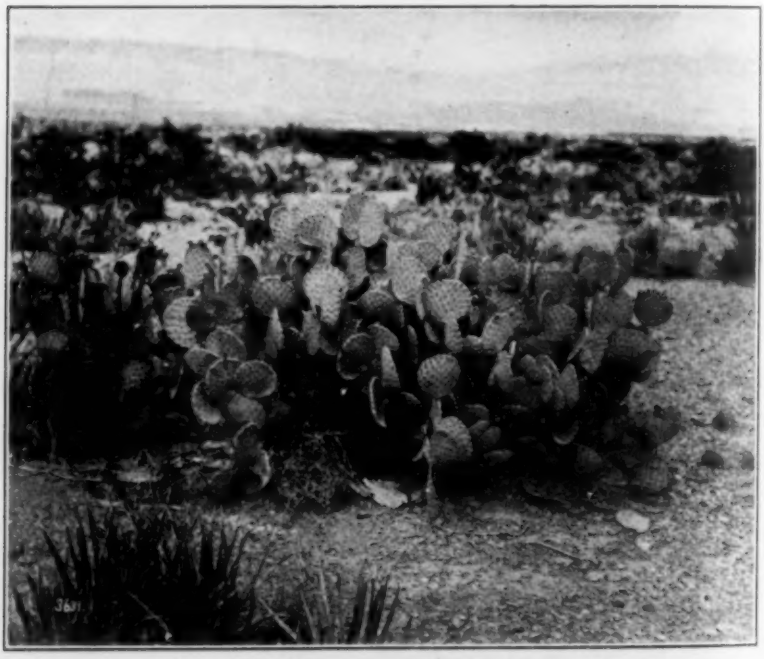
Of mammals the larger grazing forms are usually absent for the evident reason that there is comparatively little food of their liking, but the browsing ruminants—the deer, antelope and mountain sheep—are often found in local abundance. The smaller carnivores—coyotes, foxes, cats, skunks, badgers and weasels—are generally present, but the greatest abundance is usually found in the rodents, many groups of which are peculiar to desert areas. Some of these groups are highly specialized for desert life and comprise large numbers of species and subspecies found nowhere else and often found in great numbers in the very dry, hot and barren areas, where there is no open water, no possibility of obtaining subterranean water and where there is often no rain or snow or dew for months or years at a time. Even in the midst of long dry periods these desert animals are found in perfect health and good bodily condition, with abundance of internal fluids and secretions, often with the bladders well filled with water. The young are produced, and the mothers seem always to have a copious supply of milk for them as they grow up without a knowledge of what water looks like or that such a thing exists.

There has been much speculation as to how these animals obtain sufficient moisture for their needs, and many theories have been evolved. Prairie dogs and other burrowing species have been supposed to sink deep wells, but they often live where no water is available for many hundreds of feet down through solid rock formations. At first thought it would seem that they might get water from succulent food, but most of the desert vegetation contains little moisture and many of the animals live largely on dry seeds of desert plants, while some have been kept in confinement

THE SOUTHERN ARIZONA DESERTS

With an average rainfall of 7 to 10 inches a year these deserts bear scattered plants of cactus, mesquite, creosote bush, and many low shrubs of the *Compositae* called *rabbit-brush*, all of desert types and widely spaced.





THE DESERTS OF WEST TEXAS

Along the Rio Grande Valley are dry and hot slopes, by no means barren of vegetation or animal life. Cactus, creosote bushes, catsclaw, yuccas and agaves are conspicuous, while grasses and small plants are scattered here and there.

for considerable time with no other food than seeds or grain. Juicy insects and insect eggs have been thought to supply the necessary moisture, but in the stomachs of many of the species examined insect remains are scarce or entirely wanting. The conversion of starch and other carbohydrates of the food into water has been demonstrated as a chemical possibility and perhaps given more prominence than the facts would warrant.

Theories have been numerous, but actual experiments and close observations few.

By far the most important paper on the subject is by Dr. S. M. Babcock,[1] who shows how carbohydrates, fats and protein may be chemically converted into 50 to 100 per cent. of their weight of water by oxidation or molecular change within the cells of the body, thus supplying much of the water necessary for vital processes, and in some insects ample water for growth and reproduction when living on air-dried food containing only 10 per cent. of moisture. He also shows that birds and reptiles as well as insects conserve moisture by eliminating the poisonous wastes of the vital processes as dry salts of uric acid, but that mammals which have the same power of converting these food elements into water must eliminate their waste in the form of liquid urea. He further informs us that this metabolic water would be sufficient for all vital purposes in mammals but for the necessity of elimination of poisonous waste in liquid form. To what extent mammals can really live with water obtained only from relatively dry food he leaves us still in doubt.

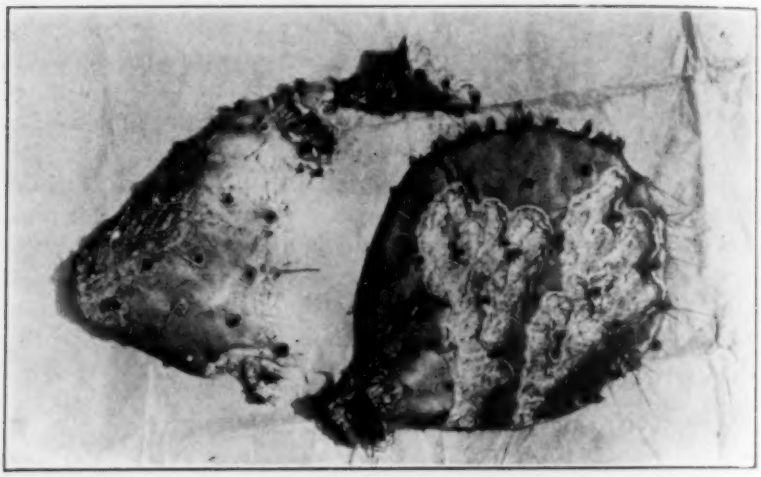
It must be granted that animals long accustomed to desert conditions have become especially adapted in habits and structure to the conservation of moisture. They have dry firm skins which retard perspiration; their feces are dry and carry away only a minute trace of moisture; they are largely nocturnal and burrowing and not exposed to the drying air of the hot days; and above all they know where to find a permanent supply of choice foods. In studying them, however, each species must be taken separately, as the habits vary widely and in even the same species may differ materially in different localities and at different seasons. The following species will serve to illustrate the habits in several groups.

Rabbits

The antelope jack rabbit (*Lepus alleni*) is a typical desert species occupying western Sonora and southern Arizona, living on dry valley slopes and mesas where for long distances no water is avail-

[1] Babcock, S. M., "Metabolic Water, its Production and Rôle in Vital Phenomena." Research Bull. 22, U. of Wis. Agri. Exp. Sta., pp. 87–181, 1912.

able. Even where open water does occur they apparently do not go near it, even in periods of long drought. The greater part of their food is green grass and growing vegetation, but throughout their range many species of cactus are abundant, and at all seasons the rabbits habitually feed on cactus pulp to any extent they wish. The large prickly pear or pad cactus (*Opuntia engelmanni*) is generally eaten more than any other species, evidently because the most abundant and least spiny cactus where they range. In Arizona most of these plants are more or less eaten by the rabbits, and some near the trails are almost entirely devoured. The stomachs of rabbits shot usually contain considerable quantities of the bright green, moist and mucilaginous pulp of the cactus pads. By weigh-



ENGELMANN CACTUS PADS

Showing how the jack rabbits eat between the spines on some and bite out the edges on others.

ing a green pad of this cactus, drying out and again weighing, I found that it lost 78 per cent. of its total weight by evaporation of water. The edible part would have a still higher water content.

The common "viznaga" or devil's head cactus (*Echinocactus wislizeni*) of the same region is also eaten when the rabbits can get at it, but usually the rigid straight and hooked spines protect it from external attack. When injured, broken or cut into, so that the rabbits can get a start on one, it is soon eaten out hollow and finally killed as its great store of moisture is lost. By splitting open one of these viznagas with an ax, quartering and leaving it exposed I found that the rabbits soon gathered and devoured all but the spiny shell. The crisp juicy flesh of this cactus showed by evaporation 94 per cent. water and the whole plant about 90 per cent.

Over sections of dry, sandy valley slopes I found numerous little pits dug a few inches deep by the jack rabbits. The bottom of each of these showed the remains of a partly eaten tuber, averaging about the size of my finger. Digging them up, I found them of various lengths with dry hard caps or scabs over the top of each where they had been previously cut off and healed over, often several of these dry caps lying close by where the tuber had been eaten at different times. The plant proved to be a member of the Purslane family (*Talinum angustissimum*), and the rather solid tubers

ENGELMANN CACTUS

Large plants are found half eaten up by jack rabbits and occasionally the whole plant is consumed down to the woody base, from which new shoots start up when the next rain comes.

showed by desiccation a 70 per cent. water content. A small portion of these tubers was often found in the rabbit stomachs and the thousands of little pits where they had been dug showed them an important source of supply of both food and moisture.

The rabbits are in part diurnal, but are active mainly at night or in the early morning and evening, when the air is cool and moist. Green grass and many plants with green foliage were regularly sought and the new leaves eaten off as fast as they appeared above ground while tender and juicy. The well-masticated contents of rabbit stomachs generally showed a mass of green vegetation with a moisture content of 78 to 82 per cent., or about the average moisture of their green food plants.

As the droppings of the rabbits are almost dry, and the urine is thick and milky and not very copious, there is evidently little loss of moisture from the bodies and a constant and ample accumulation

of it from the food. As other fresh growth dries up they still have many kinds of cactus and underground tubers and bulbs to depend upon for moist food. The same generalizations apply more or less to other species of rabbits which abound in desert regions.

Kangaroo Rats

Kangaroo rats and pocket mice fall into a group with very different habits from those of the rabbits, being mainly seed eaters, burrowers and night workers. They inhabit our driest deserts and have been credited with living indefinitely without water. In the wild state their principal food appears to be dry seeds of numerous plants, and the stomachs generally contain a starchy mass of clean white dough, with occasionally a bit of green vegetation or moist

Viznaga Cactus

The top was cut off this cactus, and two weeks later the antelope jack rabbits had left only the spiny shell and a circle of characteristic pellets around it. The cactus was not large but may have yielded 50 pounds of water.

plant tissue. There are accounts of their having been kept alive for long periods on dry seeds with no water, but in many cases I have found that after being kept for a week on dry food they are extremely thirsty and drink eagerly and repeatedly as if famished. In fact, some have died after two or three weeks without water or green or moist food. They are always eager for juicy cactus pulp, crisp lettuce leaves or green grass, although eating but little at a time. Their conservation of moisture, through dry pellets, slight deposits of urine, nocturnal and burrowing habits, evidently enables them to live with very little moisture. In many cases, however, I found where they were obtaining all the moisture they needed in the most arid sections of southern Arizona.

Dipodomys merriami, typical of its group, ranges in Lower Sonoran Zone from El Paso, Texas, west through the Gila and Colorado valleys of Arizona and eastern California in the hottest, driest part of the United States. In the dry valley south of Tucson, Arizona, during a dry winter following the unusually dry summer of 1920 they were common and in their usual plump condition. Many were caught alive for study and others dead for specimens. One caught and instantly killed in a snap trap had its pockets filled with the little juicy tubers of a small *Portulaca* that grows abundantly over the desert and is generally available an inch or two below the surface of the ground, even during a drought of several years. Enough of these were carried in the cheek pockets at one

THE VIZNAGA CACTUS

Showing recent attacks of jack rabbits and doomed to lose the large store of water it has been many years in hoarding.

time to supply moisture for several days. I did not test their moisture content, but from other plants tested should estimate them at 75 or 80 per cent. water, the rest good food.

In digging out one of these four-toed kangaroo rats I found where the burrow had touched a tuber of *Talinum angustissimum,* another plant of the Portulacaceae, with a moisture content of 70 per cent. This large tuber had been eaten into on one side and probably contained enough watery food to supply one kangaroo rat for a month. Thousands of little pits dug over the surface of the ground by small rodents show where roots and bulbs and tubers, all more or less juicy, have served as food and drink.

In the sandy washes grow an abundance of small composite bushes (*Hymenoclea monogyra*), and their long roots bring up

moisture, if any is to be had. Their white, juicy buds and sprouts starting below the surface of the ground are so much sought by the kangaroo rats that trails lead to the base of each bush, where much digging is done for this source of water and pleasant food. The sprouts are comparable to fresh, crisp head lettuce and I should estimate their water content at 90 per cent.

In captivity these little animals drink water regularly if given only dry seeds and rolled oats and get very thirsty if they are not given water in any form for a few days. They eagerly accept viznaga (cactus) pulp in place of water and eat considerable of it

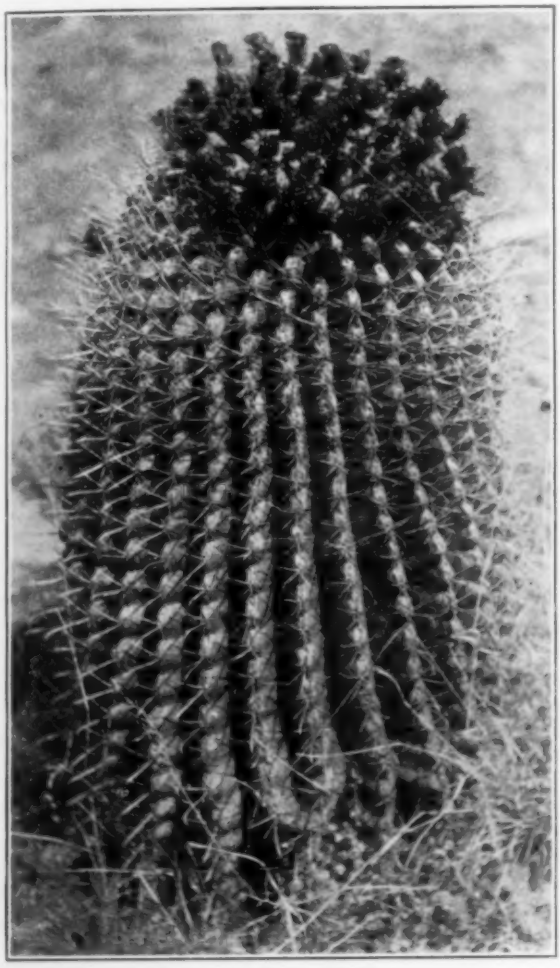
PIT DUG BY ANTELOPE JACK RABBIT

One of the characteristic pits where an antelope jack rabbit had dug down and eaten part of the juicy tuber of a *Talinum*, an abundant desert plant but so little noticed that it has no common name. Rabbit tracks were fresh in the sand.

every night, often carrying pieces into their nests to nibble at during the day. They also will eat new grass, lettuce, celery, apple and a great variety of juicy foods. One was kept in a cage for a couple of months without any water, but a grassy sod about six inches square in the cage was kept moist and as the grass grew the green tips were eaten off close down. The sod was over-grazed, but the kangaroo rat kept in good condition. Such young grass contains about 80 per cent. water, but as the blades grow older the moisture content decreases to 70, 60, and even 50 per cent.

The large, banner-tailed kangaroo rats, *Dipodomys spectabilis*, are in some ways unique in habits, building mound-houses and

storing large quantities of food to last through the winter and through long periods of drought or scarcity. They occupy the driest areas of southern Arizona, New Mexico and western Texas,

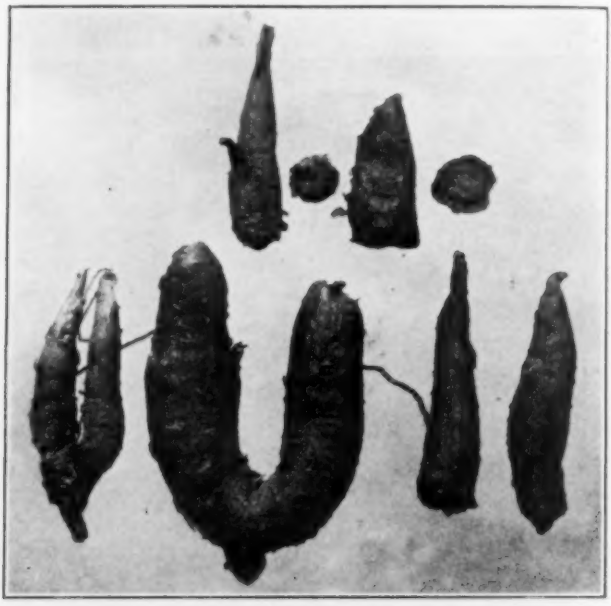


A MEDIUM-SIZED VIZNAGA

This plant, four feet high and a foot and a half in diameter, would weigh over 300 pounds and was approximately 90 per cent. water. Its crown of 50 ripe, yellow, pear-shaped fruits was still intact on March 28, 1921, owing to the effective armor of spines.

where often no water is available for months at a time. Their stores are mainly seeds and dried vegetation, but at all seasons they can find moist vegetation on or under the surface of the ground.

In captivity for nearly three years these animals have required either some green or juicy vegetation or considerable water to drink, and after a few days are evidently suffering if deprived of both. If plenty of green or moist food is supplied they will not touch the water; if not, they will drink considerable each day. In



TUBERS OF TALINUM

Many tubers, partly or almost wholly eaten by the rabbits, were dug up, photographed, weighed and dried out to get their moisture content. Woody caps or scabs formed over the tops after they were partly eaten and prevented further evaporation of their moisture.

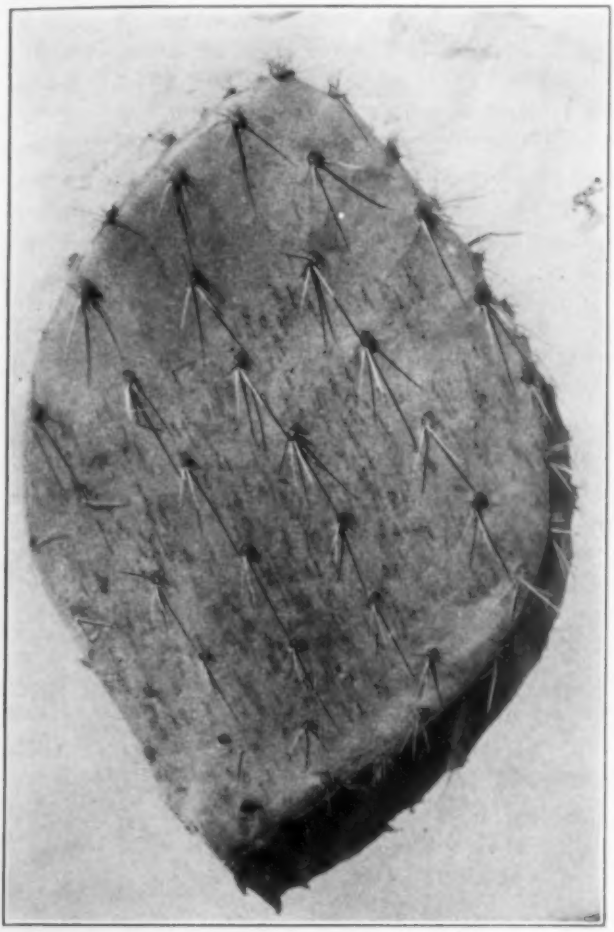
an eight days' record of food given a family of one old female and her three nearly grown young, after their food habits were well known, the following results were obtained.

GREEN AND DRY FOOD EATEN IN EIGHT DAYS

Clover	199 grams,	water content 147.7 grams	(74.3 per cent.)
Grass	12 grams,	water content 7.5 grams	(62.5 per cent.)
Lettuce	35 grams,	water content 31.5 grams	(90 per cent.)
Total	246 grams of moist food, 7.7 grams each per day.		
Rolled oats	69 grams		
Corn meal	10 grams		
Seeds	98 grams		
Total	177 grams of dry food, 5.5 grams each per day.		

Total food eaten per day by each 13.2 grams.
Water obtained by each from green food 5.8 grams.
Solid food eaten by each per day 7.4 grams.

Weight of animals, 121, 104, 99 and 98 grams = 422 grams.
Average weight of animals 105.5 grams.
Average daily food for each 7.4 grams, 7 per cent. of weight of animal.
Average daily water for each 5.8 grams, 5 per cent. of weight of animal.



ENGELMANN CACTUS

A single pad, or joint, 9 by 12 inches and half an inch thick, weighed 22 ounces, and when split open and thoroughly dried out in open air 17 ounces, losing by evaporation 78 per cent. of its weight of water. In addition to the water it is excellent food and but for the spines would have been exterminated long ago.

Their pellets were almost as dry as the dry food, but the deposits of urine were copious, probably unnecessarily so from the abundance of moist food eaten. All were in perfect health and bodily condition.

Pocket Mice

In western North Dakota in 1919 I kept some pocket mice (*Perognathus flavescens perniger* and *P. fasciatus*) in a cigar box in my grip while traveling from place to place and fed them on the various weed seeds which they liked best, mainly seeds of pigeon grass and Russian thistle. After about six weeks of such dry and simple diet I could see that they were not thriving, as they were getting very light in weight and their hair had a fuzzy, erect, unnatural look. Still, they refused to drink water and were greatly displeased or alarmed if by accident they got their noses or feet into a water dish. They would shake it off and roll and rub in dry sand until perfectly dry. One day it snowed and I sprinkled a little fine snow in their cage. They began to eat it eagerly and for a long time could not get enough. For several days I gave them snow every day, and soon they plumped up and looked as sleek and bright as ever. When the snow was gone I gave them a dish of absorbent cotton saturated with water and every day they were seen sucking at it for a few moments at a time. Later they learned to drink from a dish of open water, but in a peculiar way, dipping up a handful and turning the head to one side and licking or sucking it from the hand, repeating this five or six times, or when very thirsty as many as ten or twenty times. The usual method of drinking is apparently unknown to these little animals, but in their semi-humid range where dew falls they probably eat dewdrops in summer and snowflakes in winter.

The important fact is that on dry seeds they could go apparently six weeks without water and suffer no serious harm. Possibly, however, some green vegetation may have been offered them during that time and eaten without my knowledge, and I know that many of the seeds were not fully ripe. Now, after three years of captivity, these pocket mice occasionally get in poor condition, look rough and fuzzy, and I find they are very thirsty. When given plenty of fresh lettuce leaves, which run as high as 95 per cent. water, they keep in good condition without other water.

Gophers

Many species of pocket gophers occupy the desert region, but mainly in the more moist and fertile bottomlands or the mountain valleys where there is considerable rainfall and a richer growth of vegetation. A number of species, however, live by choice or necessity on very dry and barren valley slopes where it would be impossible to obtain water except at long intervals. They live mainly under ground in closed tunnels and feed on roots and bulbs en-

countered in extending their tunnels and on such green vegetation as they can find near their doorways when the burrows are opened for throwing out earth. As much of the desert food and moisture are stored under ground, the gopher's manner of living is most advantageous.

Several species of these little burrowers kept in captivity for a year or less time have lived largely on moist food, green vegetables, roots, tubers or succulent foliage. They seem never to drink water and carefully avoid touching it if placed in their cages.

Ground Squirrels

A little desert ground squirrel (*Citellus tereticaudus*) taken on April 18, 1911, near Continental, Arizona, had its stomach about half full of moist food, about 90 per cent. green vegetation, five per cent. pulp of tuberous or bulbous roots, and five per cent. small insects. The contents weighed 12.2 grams while fresh, 2.2 grams when dry, losing 9 grams or 81.2 per cent. of water by evaporation. This is about the moisture content of succulent vegetation, and considering the dry pellets of these squirrels evidently leaves abundance of moisture in the system. In captivity for over a year one of these little squirrels was healthy and apparently contented on a diet of seeds, grain, apple, lettuce and other green foods. Apparently he never touched the water that was occasionally put in his cage, and where he was caught there was no possibility of his getting water.

The little spotted ground squirrel (*Citellus spilosomo macrospilotus*) was also kept for about a year on the same kind of foods and with the same negative results in regard to drinking.

The antelope squirrels, sometimes called chipmunks because they have one stripe along each side, are typical of the deserts. In Arizona I found them living through a dry winter very largely on the seeds and pulp of cactus fruit, the big yellow pear-shaped capsules of viznaga. Their stomachs were found full of the little moist black seeds, chewed-up shells and all, and mixed with the juicy pulp of the capsule. Dried out in the open air the seeds lost 34 per cent., and the pulp 85 per cent. of water.

Grasshopper Mice

The grasshopper mice (*Onychomys*) are common in the driest areas, but their food is largely insects and other small animals, which derive their moisture from plants or other plant-fed life. While in the wild state these mice seem entirely independent of free water, in captivity they drink water or eat juicy vegetation

and suffer if long without an adequate supply of water or moist food. Juicy crickets, grasshoppers, scorpions, caterpillars and other larvæ form a large part of their food. These are taken on or under the surface of the ground and as only the fleshy or moist parts are eaten probably contain all the moisture required by the little nocturnal, burrowing mice. Dr. Babcock gives the water content of smooth caterpillars as 83 to 85 per cent. and beetles 50 to 62 per cent.

THE HOME OF THE MERRIAM KANGAROO RAT

Is down deep in the ground, usually under a thorny bush where there is good protection and in summer a little shade. Usually the doorways are firmly packed with earth after the occupant retires for the day.

SHREWS

One genus of shrews (*Notiosorex*) is also an inhabitant of the desert region, but the individuals are so rare that little is known of their habits except that their food is mainly insects.

BATS

The bats, however, while living on the lighter and drier flying insects are exceedingly thirsty animals, rarely found beyond reach of open water, of which they drink each evening before beginning to feed. Free of wing they have not acquired the adaptations of the more restricted rodents.

Much information is available on food and water habits of other species, but these few examples seem to indicate that desert rodents, with their acquired conservation and physiological production of moisture in addition to nocturnal and burrowing habits,

are able at all times to obtain plant-gathered or plant-stored moisture sufficient for their needs. In fact, many species require so little moisture above that chemically derived from their food that only a trace of moisture-laden vegetation is found in their stomachs.

THE LITTLE FOUR-TOED MERRIAM KANGAROO RAT

Lives only in the driest and hottest of our deserts, but he lives under ground in the daytime and does all his work at night when the air is cool and comparatively moist.

PLANTS EATEN BY DESERT MAMMALS AND THEIR AVERAGE PERCENTAGE OF WATER

Cactus—viznaga, inside part 94 per cent.
Cactus—viznaga, whole plant 90 per cent.
Cactus—viznaga, whole fruit 70 per cent. (without seeds 85, seeds 34).
Cactus—prickly pear, whole plant, 78 per cent.
Cactus—prickly pear, edible part 84 per cent. (estimated).
Hymenoclea monogyra, underground sprouts 90 per cent. (estimated).
Wild morning glory (*Evolvulus*), young leaves 70 per cent. (approximately).
Grass, young green blades, 80 per cent. (older blades 50 to 70).
Pigweed leaves (*Chenipodium*), 75 per cent.
Talinum tubers, 70 per cent.
Portulaca tubers, 75 per cent. (estimated).

RUMINANTS

The ruminants are in another class of feeders for which we lack important data. Still, we know that mountain sheep and mule deer live permanently where there is no known source of water supply,

that antelope remain in open desert valleys at long distances from open water without coming regularly if at all to watering places, that cattle and horses will often remain out on the range for three or four days at a time without water if there is fresh new grass or other juicy vegetation, although they require water daily when on dry feed. Domestic sheep will usually go for several days without water if any green vegetation is available, and on fresh green grass or weeds in spring will sometimes remain for twenty or thirty days without drinking and suffer no harm. In green food the carbohydrates are surely not sufficient to furnish much water,

A Typical Mound House of the Large Kangaroo Rats

In arid western Texas where the creosote bush is the dominant feature of vegetation, these mounds are a common feature of the landscape.

but owing to the dry pellets voided by deer, sheep and many rodents there is a considerable excess of moisture left in the system.

Thirsty Animals

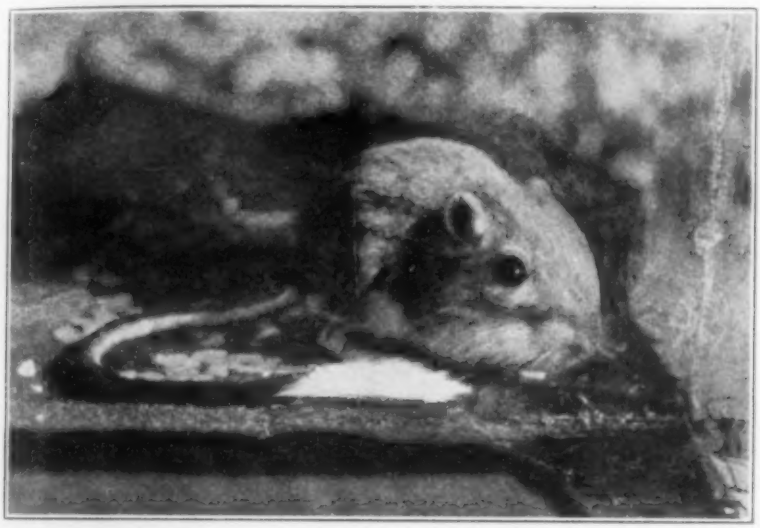
The opposite extreme of water consumption is shown by such animals as the beavers, muskrats and eastern meadow mice, living usually in or near the water and as observed in captivity, drinking heartily several times a day, although their food is largely of moist or juicy vegetation.

The eastern gray squirrels require water once or twice a day and drink a considerable amount at a time. In fact, they will not long remain where water is not available. These extremes of habit in regard to water consumed are apparently due to physiological

adjustment of the system, but to what extent this adjustment is controllable or capable of variation within a species is not well understood. A muskrat is not more vigorous, well developed or healthy than a kangaroo rat, but either would soon die in the environment of the other.

Water Required By Man

In June, 1889, the section foreman at Taena, Arizona, a station on the S. P. Railroad between Maricopa and Yuma, told me that four gallons of water to a man was the least amount on which he could keep his crew at work for 10 hours a day along the railroad



The Banner-tailed Kangaroo Rat

This is the largest of the four-toed group, conspicuous by its large mounds in the desert areas of southern Arizona and New Mexico and western Texas.

in hot weather, but at the same time I found that with a gallon canteen of water I could tramp over the valley for about six hours in a temperature of 105 to 110 in the shade, and no shade where I was. These tests, however, are under strenuous exertions which produce the copious perspiration necessary to cool the body by rapid evaporation. Men and horses perspire freely under muscular exertion, oxen and dogs but little, and many animals apparently not at all.

In the Death Valley country in the scorching heat of June, 1891, a gallon canteen of warm water would keep me comfortable all day in the saddle, while others less accustomed to the desert could barely survive on twice that amount of water. I also found

by some severe tests that thirst was greatly lessened by the moist air of night and that comparatively little water was needed while sleeping on the ground during the hours of darkness. We know the native Indians of the deserts school themselves to go a long time without water and when necessary to get a supply from the fruit and pulp of cactus and other plants which store it.

As we all know, the character of our food has a marked effect on our thirst and the amount of water we require. Also, if we do not drink all the water we want, that for considerable time no bad effects are noticed. Violent exercise and perspiration soon develop thirst and we suffer if the lost moisture is not returned to the system and the waste products removed.

THE DESERT SPECIES OF POCKET GOPHERS

Live almost entirely underground and feed on roots, bulbs, tubers and such green vegetation as they find near the doorways, which are occasionally opened for the exit of surplus earth from their burrows. They apparently never drink water.

In a Department of Agriculture bulletin I find the average percentage of water given for various foods as follows:

Fresh lettuce,	94.7 per cent.	
Fresh spinach,	92.3 " "	
Fresh cabbage,	91.5 " "	
Whole milk,	87.3 " "	
Fresh apples,	84.0 " "	
White potatoes,	78.3 " "	
Beef steak,	63.1 " "	
White bread,	39.0 " "	(my own test)
Corn meal,	12.5 " "	
Whole rice,	11.0 " "	
Wheat flour,	10.8 " "	

In a careful two days' test of water taken into and pressed out of my own system I found that while only sufficient water to prevent thirst was taken, 26 ounces with an elimination of 38½ ounces one day and 30 ounces with an elimination of 42½ ounces the next, each day showed 12½ ounces of water to have come from my food. All liquids, soup, milk and fruit juice were included in the amount drunk. Otherwise the food was of the usual combination of meats, vegetables, cereals, breads and fruits. By increasing the vegetables, fruits and water-producing foods it seems probable that I might live comfortably for a considerable time, possibly

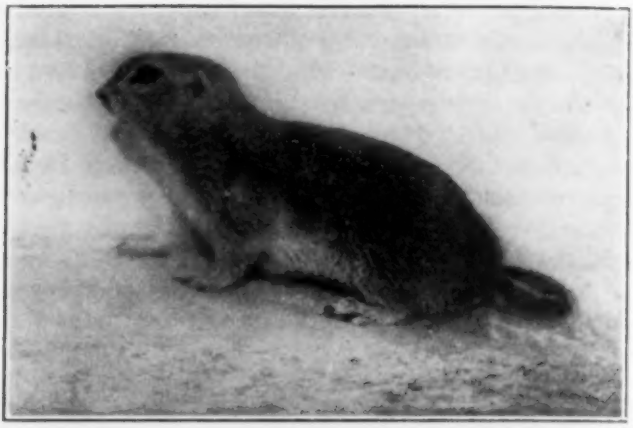
THE ANTELOPE SQUIRREL

Is active the year around in the deserts, feeding on green vegetation, green seeds and fruit, and in winter to a great extent on the seeds and fruit of viznaga and other kinds of cactus.

indefinitely, without drinking any liquids, providing, of course, that I was not taking violent exercise or exposed to dry, hot weather. If moving about only at night, sleeping all day in an underground burrow and with a few other slight advantages of adaptation to desert conditions, I might get enough moisture from my food for a healthy existence and become a true desert mammal.

CONCLUSIONS

These scattered observations and tests suggest the possible value of further investigations, requiring more time and better laboratory facilities. The bodily condition, gain and loss of weight,



THE LITTLE ROUND-TAILED DESERT GROUND SQUIRREL

Has no use for water in a free state but selects the tender, juicy young plants for food, and when the weather becomes very hot and dry in midsummer goes deep into his burrow and sleeps until the next February or March.

POCKET MICE

These little pocket mice belong to a desert group of rodents but have a wider range than the kangaroo rats and some of the species reach into the edges of more humid areas. Their bulging cheeks are partly filled with rolled oats and weed seeds to be eaten at leisure.

effect on growth, breeding, hibernation, aestivation and general welfare of not only desert but humid area species due to food and water conditions would be well worth careful study. The relative water productivity of different foods and combinations of foods should be determined for species in different groups of mammals under both normal and extreme conditions of climate. Some of the facts thus obtained might have an important bearing on the control of noxious species, on better development of ranges for game and domestic animals and even give to man a wider range of adaptation to extremes of climate.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

HAS SCIENCE REACHED ITS LIMIT?

"What is there left for me to discover?" is the common thought of the student as he looks about the library with shelves packed with books or the museum with cases filled with neatly labeled specimens. He realizes that when he enters upon research he is competing not only with his contemporaries, but with all his predecessors. No tariff can protect him from the pauper labor of antiquity.

"What are you scientists going to do when you find out everything about everything?" is a common remark of visitors to a laboratory. The scientist will doubtless reply that life is not long enough to find out everything about anything, but even he is apt to harbor the delusion that all the really big things have now been discovered and that future investigators will find pretty poor picking. Some scientists have been so rash as to put this opinion into print, much to the amusement of later generations. For instance, the great French mineralogist, Haüy, wrote at the beginning of the nineteenth century:

"Electricity enriched by the labor of so many distinguished physicists seems to have reached a time when a science has no more important steps before it and only leaves to those who cultivate it the hope of confirming the discoveries of their predecessors and of casting a brighter light on the truths revealed."

But we count this the beginning of our knowledge of electricity rather than its end, for over in London at this very time young Michael Faraday in his basement room at the Royal Institution was working out the relationship between electricity and magnetism which has led to the dynamo and the radio.

One might think that such a blunder as this would have made later scientists cautious about thinking that nothing much remained to discover, but no, for we find in 1894 the catalogue of one of the largest universities in the United States publishing at the head of its list of courses in physics the following discouraging statement:

"While it is never safe to affirm that the future of physical science has no marvels in store. . . . it seems probable that most of the grand underlying principles have been firmly established and that further advances are to be sought chiefly in the rigorous application of these principles to all the phenomena which come under our notice. . . . An eminent scientist has remarked that the future truths of physical science are to be looked for in the sixth place of decimals."

But the very next year Röntgen discovered the X-rays that led to radium and the electron.

When Newton laid down the law of gravitation the solar system was reduced to a simple mechanism and the movements of the planets could be accurately predicted. What was there left for the astronomer to do?

Bigger telescopes would doubtless reveal more satellites and show finer markings on the moon, but how could we ever hope to learn anything about the composition of the heavenly bodies? Yet now we can know how the electrons behave inside the atoms of stars whose light requires thousands of years to reach us, and Einstein has pointed out that even Newton's law requires modification.

Some branches of science may well have reached a terminal. I suppose it is safe to say that about all the large animals on the earth have been discovered and described. It is true that the okapi, which is almost as conspicuous as a giraffe, managed to keep himself concealed in the African jungle until 1900, but not many such can have escaped the eye of the zoologist. But he can make no end of queer looking animals when zoology becomes a constructive instead of a descriptive science.

The scientific discoveries of the twentieth century have not only been more numerous than in any previous century, but they have been greater. Our investigators are not engaged in verifying the sixth decimal, but are projecting far-reaching and fundamental theories.

When you throw wood on a campfire in the night you expand the lighted area, but you also extend the circle of the surrounding darkness. So it is with science. With each increase in enlightenment a larger circle of surrounding ignorance is disclosed.

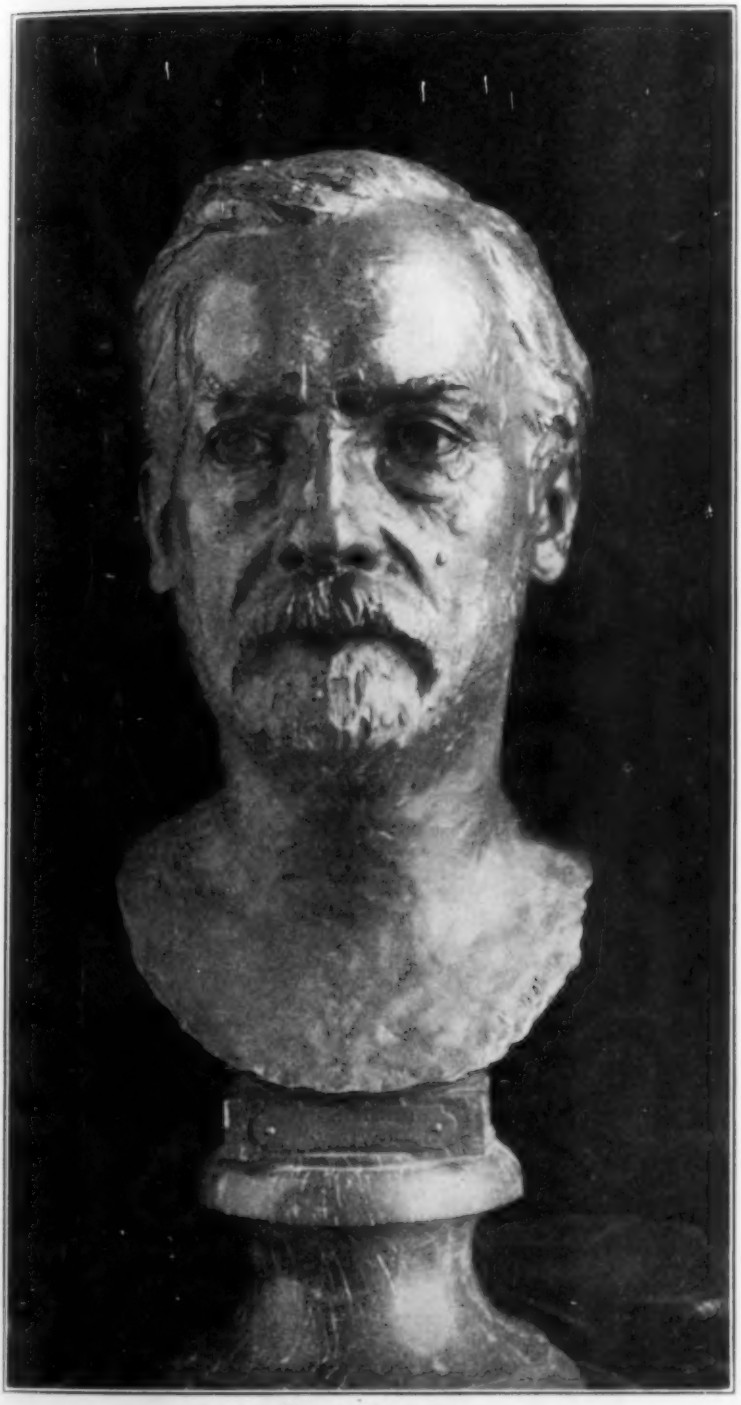
RELIGION AND SCIENCE

Timid souls who have become alarmed at the idea that religion and science are inevitable antagonists should be assured by the "Joint Statement upon the Relations of Religion and Science," signed by a number of the foremost scientists, religious leaders and men of affairs of the United States. These thirty-five distinguished thinkers in various fields found it easy to agree upon a simple statement of their opinion of the relation of religion and science and their belief that both have a place in modern life. No one can question either the ability or sincerity of such men as these, and, since their adhesion to the declaration is purely voluntary, it is evident that they find no essential incompatibility between a personal religious faith and a scientific view of the universe.

The list of signers could be extended indefinitely; in fact, the statement probably represents in general the position of most of the educated and moderate minded men of our time and country.

It is a curious feature of the present situation that the laity are more alarmed over the advances of science than the clergy. That is, those who know the most about theology and who have most at stake in the church are most willing to welcome historical criticism and scientific research. The real conflict is not between science and religion as such, but rather between dogmatic and intolerant religionists and scientists, on the one side, and liberal and tolerant religionists and scientists, on the other side. It is more a difference of temperament than of opinion. The effort to fetter freedom of investigation or to force thought into fixed formulas is equally fatal in science and religion.

Overmuch fear of heresy indicates lack of faith. Scientific men have such absolute confidence in the validity of the scientific method that they permit their most fundamental principles to be challenged even in their own societies. Chemists listen without a shudder to destructive attacks



BUST OF PASTEUR

Presented by the Pasteur Institute at Paris to the American Museum of Natural History, New York

DR. WILLIAM S. THAYER, OF THE JOHNS HOPKINS UNIVERSITY; AMBASSADOR MYRON T. HERRICK, THE HONORABLE S. P. SPENCER AND DR. WILLIAM H. WELCH, OF THE JOHNS HOPKINS UNIVERSITY

The photograph was taken at the Sorbonne during the celebration in honor of the centenary of Pasteur's birth.

upon the immutability of the elements and the indivisibility of the atom. The Royal Society of London even applauds a speaker who sets an upstart foreigner like Einstein above Newton, one of its oldest and most venerated members.

The papers have reported a half dozen cases of professors who have been dismissed from educational institutions under ecclesiastical control for teaching evolution but there has been no retaliation from those whom some call the "enemies of religion." I never heard of the National Academy of Sciences expelling a member because he was suspected of being a Presbyterian or of the American Association for the Advancement of Science blackballing a man because he had been baptized. Girard College is the only institution that excludes clergymen by charter, and I understand that the doorkeeper there is not very vigilant in searching every visitor to see if he has a dogma concealed about his person. If we begin to rewrite our text-books in science to suit a single sect, or section of a sect, we may soon have Methodist and Baptist zoologies, Protestant and Catholic chemistries, Jewish and Christian theories of gravitation, as we now have northern and southern histories, and proletarian and capitalistic economics.

Science and religion, properly understood, need never conflict, but should always cooperate in the advancement of the human race, for each supplies what the other lacks. Science provides the means by which human toil and suffering may be alleviated and shows how human life may be lengthened and enhanced. Religion gives inspiration to the individual, an aspiration to a high ideal. Science gives eyes to religion. Religion gives a heart to science. Knowledge is power. But power is impotent unless set in action, and dangerous if set in action by the wrong motive. Religion, unless enlightened by science, wastes its energies in vague longings or in fruitless and sometimes harmful efforts to remedy bodily or social ills.

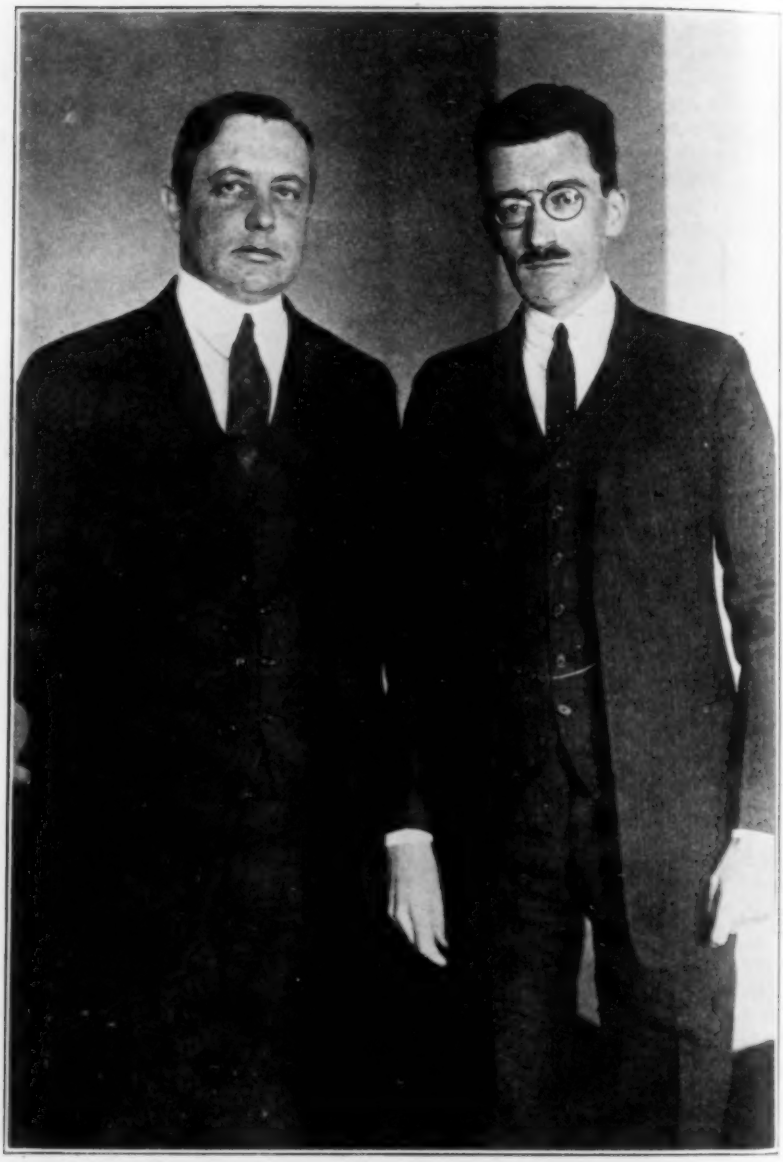
Science may discover what conduct is most conducive to human welfare in the future. But science as such can not go beyond this. It can point out the best way, but it can not inspire the individual voluntarily to follow it against his personal interest. Mere knowledge can not of itself supply the motive for self-sacrifice for others or for the future. It can not make a mother risk her life for her child or a man risk his for his country. The altruistic impulse is a religious instinct, whether it is recognized as such or not. Science can supply the motive power. Religion must supply the motive.

THE FIGHT AGAINST THE POTATO

What would we do without the potato? None is so poor that he can not afford to eat it. None is so rich that he can afford to disdain it. If all the potato plants of Europe should suddenly perish and prove irreplaceable a large part of the population would have to starve or emigrate.

Yet the people fought the potato as though it were the plague when it was first introduced into Europe. They were used to the plague and regarded it as proper punishment for their sins, but the potato, coming from the wild west of America, was new and therefore to be feared.

Sir Francis Drake is supposed to have brought the potato to England in 1586, having perhaps taken the tubers, in the course of one of his privateering cruises, from some Spanish vessel, together with other less valu-



Wide World Photo

CHARLES C. CONCANNON AND FREDERICK E. BREITHUT

Mr. Concannon is the newly appointed chief of the Chemical Division of the Department of Commerce. Dr. Frederick E. Breithut, of New York City, will investigate the chemical and dye industry of Germany for the Department. Dr. Breithut will head a commission with headquarters in Berlin.

able booty, such as gold and gems. Anyhow, he is credited with it by the Germans who erected a monument in his honor at Offenburg in 1854 and struck off a medal to the British admiral as the savior of Germany in 1916 when a big potato crop enabled them to hold out another year.

But such honors always come by slow freight. It took people a hundred years or more to learn that potatoes were good for them to eat. They fed them to their pigs and cattle which, not having the prejudices of rational men, took to them readily.

The Germans also fed their prisoners of war on potatoes and it happened that one of them was a French chemist, Parmentier, who, having been captured in 1758, was held a prisoner in Hanover for five years and had to live largely on potatoes. One would have thought he would have acquired a distaste for them but on the contrary when he was released he urged his countrymen to cultivate the potato as a vegetable, "that in Times of Necessity can be substituted for Ordinary Food." But the French, even though starving, would not eat potatoes until finally Parmentier persuaded the king and queen to taste some and wear a bouquet of the blossoms. The people, seeing that the king and queen were not poisoned, consented to sample them for themselves.

In 1728 an attempt was made to introduce potatoes into Scotland, but they were denounced from the pulpit on two contradictory counts; that they were not mentioned in the Bible and so not fit food for Christians, and that they were the forbidden fruit, the cause of Adam's fall. They were accused of causing leprosy and fever.

In England the effort of the Royal Society to promote the cultivation of the potato was suspected to be a conspiracy of capitalists to oppress the poor. The labor leader, William Corbett, said, "It has become of late the fashion to extol the virtues of potatoes as it has been to admire the writings of Milton and Shakespeare," and he declared the workingmen ought not to be induced to live on such cattle food.

When the British army was sent to fight in Flanders—not in 1914 but a hundred years before—they acquired two shocking habits. They learned to swear terribly and they learned to eat potatoes. The monks of Bruges had introduced their cultivation by compelling their tenants to pay part of their dues in potatoes. The farmers, seeing that the monks throve on them, began to save some of the crop for their own use.

In Germany our own Benjamin Thompson, having become Count Rumford in Bavaria, undertook to clean the beggars out of Munich. When he had rounded them up he had to feed them and being a student of dietetics he decided that potato soup was the cheapest and most nutritious food he could find. But he had to smuggle the potatoes into the kitchen secretly, otherwise he would have had a hunger strike in the poorhouse.

And so, thanks to the initiative of scientists, kings and monks, and to the involuntary assistance of pigs, prisoners and paupers, the world got the inestimable benefit of potatoes. I wonder what we are fighting to-day as wrong-headedly and vainly as potatoes were fought by our forefathers.

SHARK-TOWED SUBMARINES

It is funny that anybody should be surprised at a parliamentary allusion to Great Britain's determination to remain mistress of the seas when she has made that plain by legislation, poetry and action for the last four hundred years. It is only a few years since as her associate in the late war we joined in the singing of

Rule Britannia! rule the waves!
All thine shall be the subject main,
And every shore it circles thine.

But it is not so commonly known that one of the proposed methods by which Great Britain was to hold her supremacy of the seas was the use of submarines towed by sharks. The inventor of this ingenious scheme was Dr. Erasmus Darwin, grandfather of Charles, who derived more than one hint for his theory of evolution from Erasmus Darwin's volume of versified science, "The Botanic Garden."

The most famous passage in this curious work is that in which Erasmus Darwin anticipates the automobile, the steam tug and the airplane:

Soon shall thy arm, unconquered Steam! afar
Drag the slow barge, or drive the rapid car;
Or on wide-waving wings expanded bear
The flying-chariot through the fields of air.
Fair crews triumphant, leaning from above,
Shall wave their fluttering 'kerchiefs as they move;
Or warrior-bands alarm the gaping crowd,
And armies shrink beneath the shadowy cloud.

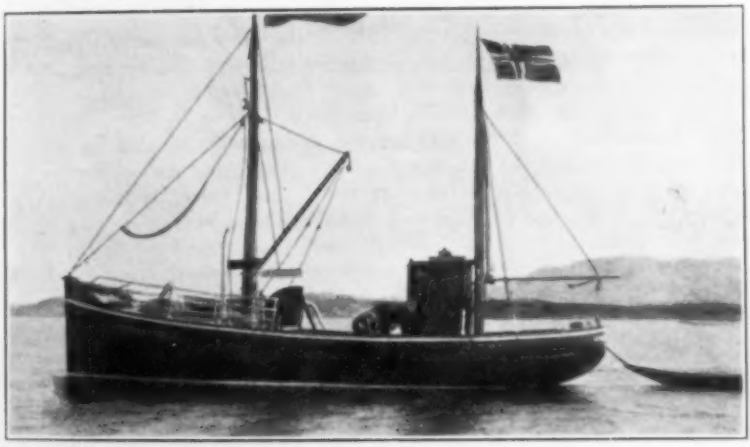
This is a good guess for 1789, although it is not steam but gasoline that we are using for automobiles and airplanes. But Grandfather Darwin could not anticipate the internal combustion engine, and he knew that steam would not work under water so when he undertook to describe a submarine he could not see how the boat could be propelled unless fish could be harnessed to it. So he wrote:

Led by the Sage, lo! Britain's sons shall guide
Huge *Sea-Balloons* beneath the tossing tide;
The diving castles, roof'd with spheric glass,
Ribbed with strong oak and barr'd with bolts of brass,
Buoy'd with pure air shall endless tracts pursue,
And Priestley's hand the vital flood renew.
Then shall Britannia rule the wealthy realms,
Which Ocean's wide insatiate wave o'er whelms:
Confine in netted bowers his scaly flocks,
Part his blue plains, and people all his rocks,
Deep, in warm waves beneath the Line that roll,
Beneath the shadowy ice-isles of the Pole,
Onward, through bright meandering vales, afar,
Obedient sharks shall trail her sceptered car,
With harness'd necks the pearly flood disturb
Stretch the silk reign, and champ the silver curb.

Absurd as this is as science and poor as it is as poetry, yet it has many points of interest. The author solved the question of submarine ventilation by the means now employed, that is, the renovation of the air by oxygen gas, which had been discovered only fifteen years before by his friend, Joseph Priestley, a preacher-chemist who was driven out of England and came to America because of his political and religious nonconformity.

But Erasmus Darwin made a bad guess in his surmise as to the motive power of the future submarine. Man has never been able to train to harness any animals of the sea. His control stops with the shore. And now he is getting ready to dismiss the ox and horse from their long servi-

MARINE BIOLOGICAL STATION OF THE BERGEN MUSEUM



"HERMAN FRIELE"

Collecting yacht of the Marine Biological Station of the Bergen Museum

tude and rely instead upon the inanimate energy of fuel and falls to run his slow barges and rapid cars as well as his flying-chariots and sea-balloons.

THE NEW WORLD

The world we live in is a new world. Nobody ever lived in such a world before. It is a bigger world because there are more people in it. It is a smaller world because one can get around it quicker. It is a more complex world because of the many new forces that have entered into it. It is a simpler world to understand for it has been more thoroughly studied and classified. It is for the first time a known world, at least a knowable world. Practically all parts of it have now been explored. Most parts of it have been accurately mapped. Since Amundsen has visited the south pole and Peary has visited the north pole, no place on the globe's surface can be regarded as inaccessible.

We can now for the first time take stock of our resources and calculate our potentialities. We know just how much land we have at our disposal. We know that we shall never have any more land. We know pretty well what this land will grow and what it will not grow. We know how much food and what kinds each individual needs. We can then figure out how many people the earth can support at any given standard of life.

We can not see underground, but from looking at the edges of the strata where it is tipped up and from boring into it a mile or more in various places, we can tell about how much coal and oil, iron and copper, potash and phosphate, we have to go on, and we know that we can never get any more when this runs out.

In this new world of ours there is no more free land. The open range has gone forever. It is all staked out in private claims. Some flag floats over every bit of dry land. The last of the maverick territory, Spitsbergen, was caught and branded during the late war. This means that if any nation is to get more land it must get from some other nation.

There are many more nations than there were in the nineteenth century. Some twenty or more infant independencies are struggling for existence. If we call the cradle roll of the new-born nationalities we find them scattered from the Balkans to the Baltic, from Ireland to Azerbaijan, from Palestine to Vladivostok, all new and untried factors in the world's affairs.

War is new. It is fought with weapons hitherto unknown. Commerce is new. Strange commodities are carried by novel channels of trade. Finance is new. The old standard is lost and no one knows which nations are bankrupt and which solvent. Science is new. It is outgrowing its clothes, its old formulas and theories. Consequently it is more difficult than ever to predict the future or to apply the lessons of the past.

The historian, Seeley, once remarked: "When I hear a man say, 'History teaches us,' I say to myself that man is going to tell a lie and he always does." History can not help us much because it is the history of another and very different world from ours. So many unknown quantities have been introduced into our present problem that it can not be solved by the old rules.